BM@N Meeting 30.01.2020

Production of Λ hyperons in 4 and 4.5 A GeV carbon-nucleus interactions

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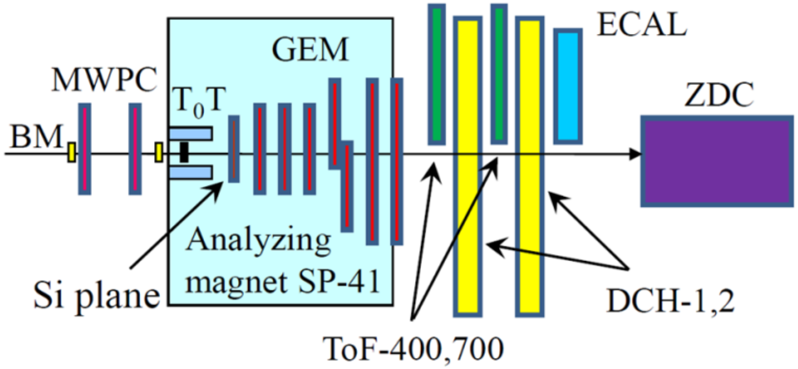
Outline

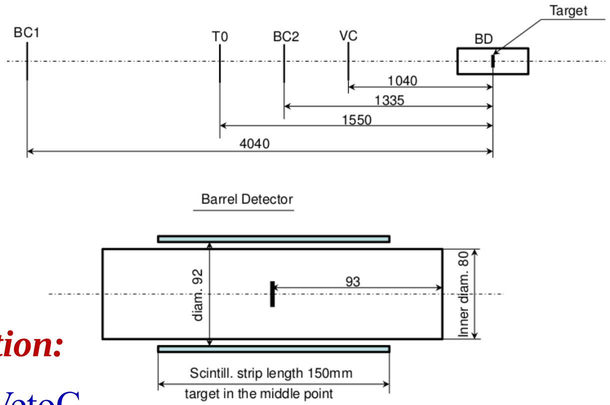
1. BM@N detector set-up in carbon run (Run 6 (54))
2. Data analysis at 4 and 4.5A GeV
   - ✓ Reconstructed signal of Λ (dN/dy & dN/p_T spectra)
   - ✓ Data - MC agreement: multiplicity, momentum spectra
   - ✓ Cross section and yields of Λ in (y,p_T) measurement range
   - ✓ Reconstructed p_T spectra of Λ and extracted inverse slopes
   - ✓ Energy dependence of Λ yields and comparison with models
3. Summary

Configuration of BM@N detector

BM@N set-up in carbon run

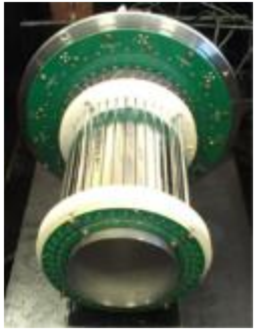


Beam and trigger detectors



Trigger condition:

BC1·BC2·notVetoC
BD ≥ 2 (C+C)
BD ≥ 3 (C+Al,Cu,Pb)



Program in carbon run:

- Test / calibrate ToF, T0+Trigger barrel detector, full ZDC, part of ECAL
- Trace beam through detectors, align detectors, measure beam momentum in mag. field of 0.3–0.85 T
- Measure inelastic reactions C + target → X with carbon beam energies of 3.5 - 4.5 GeV/n on targets C, Al, Cu, Pb

Triggers

Number of triggered events, beam fluxes and integrated luminosities collected in interactions of the carbon beam of 4 and 4.5A GeV with different targets.

ε_{pileup} suppression factors

Selection	4 AGeV	4.5 AGeV
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

T0=1 BC2=1 Veto=0 within 1.5 μs

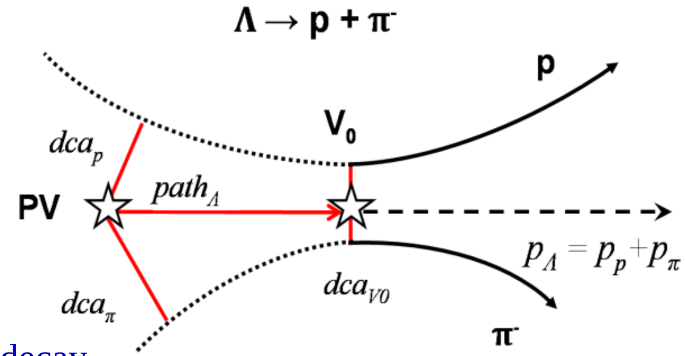
Interactions, target thickness	Number of triggers / 10^6	Integrated beam flux / 10^7	Integrated luminosity / $10^{30}cm^{-2}$
4A GeV, *C*+*C* (9 mm)	3.98	6.07	6.06
4A GeV, *C*+*Al* (12 mm)	3.81	3.31	2.39
4A GeV, *C*+*Cu* (5 mm)	4.77	4.71	2.00
4A GeV, *C*+*Pb* (10 mm)	0.67	0.67	0.22

Interactions, target thickness	Number of triggers /10^6	Integrated beam flux /10^7	Integrated luminosity / 10^{30} cm^{-2}
4.5A GeV, *C*+*C* (9 mm)	2.93	4.70	4.69
4.5A GeV, *C*+*Al* (12 mm)	3.58	4.98	3.60
4.5A GeV, *C*+*Cu* (5 mm)	5.30	7.21	3.06
4.5A GeV, *C*+*Pb* (10 mm)	2.33	2.58	0.84

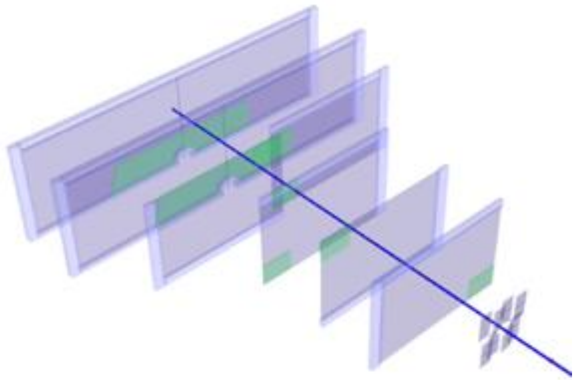
Event selection

Selection criteria:

- Number of hits in 1 Si + 6 GEM per track **> 3** (7 detectors in total)
- Momentum range of positive tracks: $\boldsymbol{p_{pos}}$**< 3.9 (4.4)** GeV/*c* for 4 (4.5)A GeV
- Momentum range of negative tracks: $\boldsymbol{p_{neg}}$**>0.3** GeV/*c*
- Distance of minimum approach of *V0* tracks: ***dca*****< 1** cm
- Distance between *V0* and primary vertex: ***path* > 2.0 - 2.5** cm (target dependent)



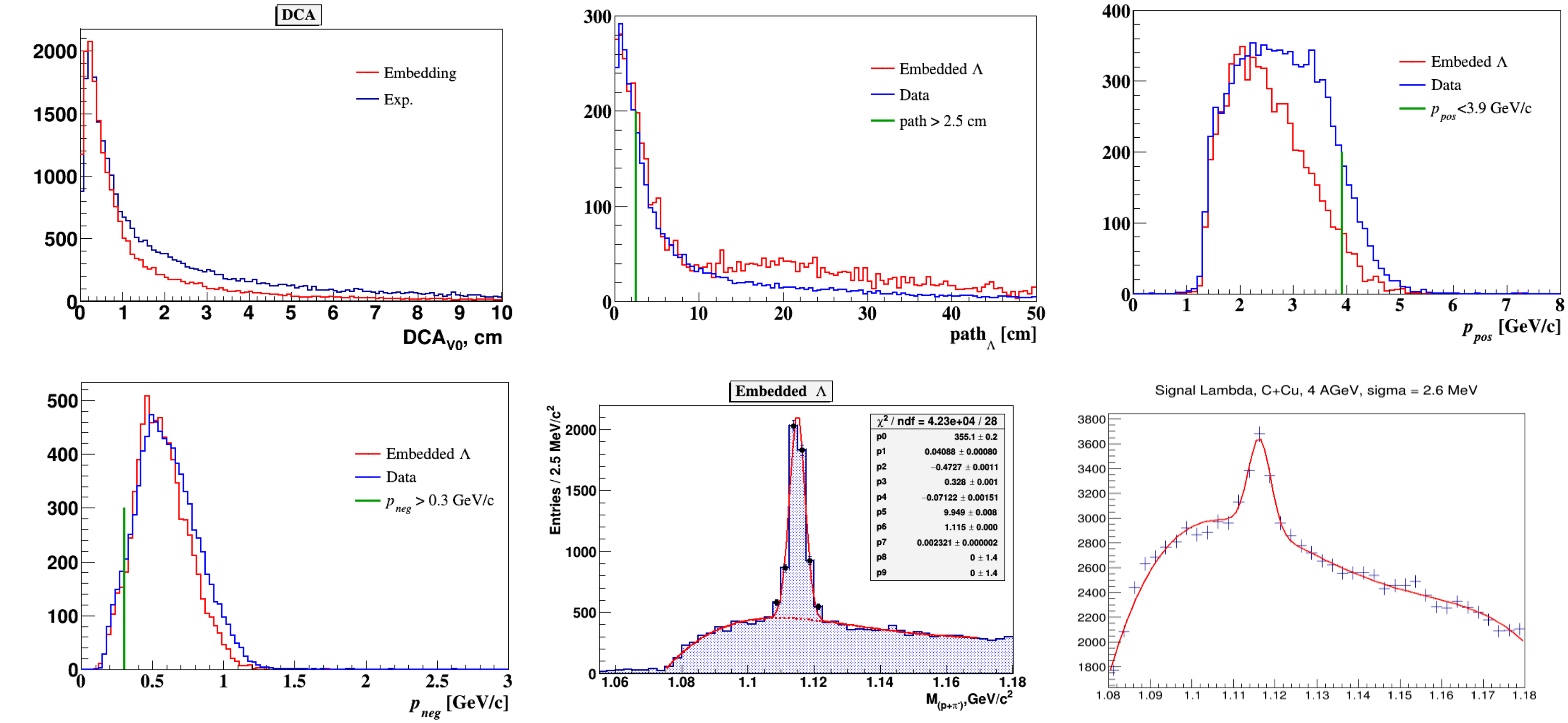
Central tracker in carbon run



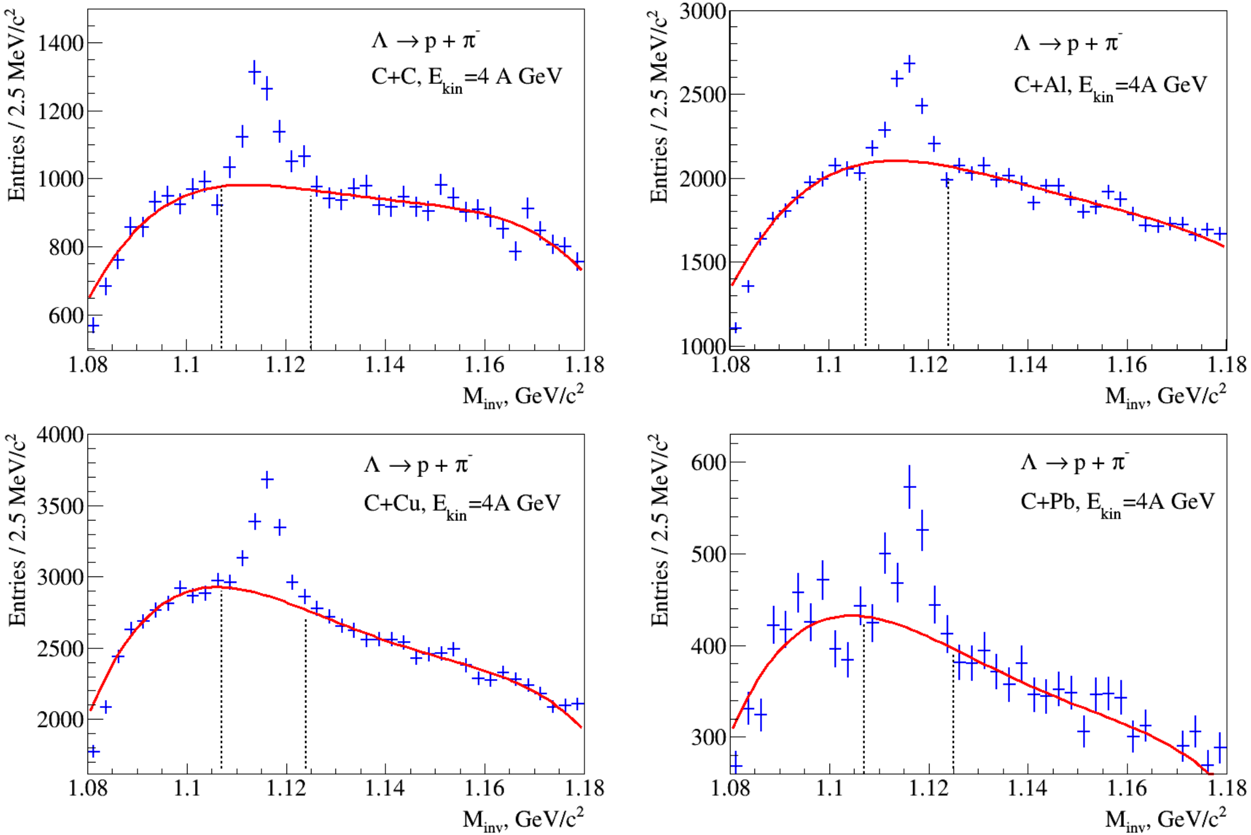
Event topology:

PV – primary vertex
V_0 – vertex of hyperon decay
dca – distance of the closest approach
path – decay length

Control plots: data vs embedding



Λ in *C+C*, *Al*, *Cu*, *Pb* interactions (4A GeV)



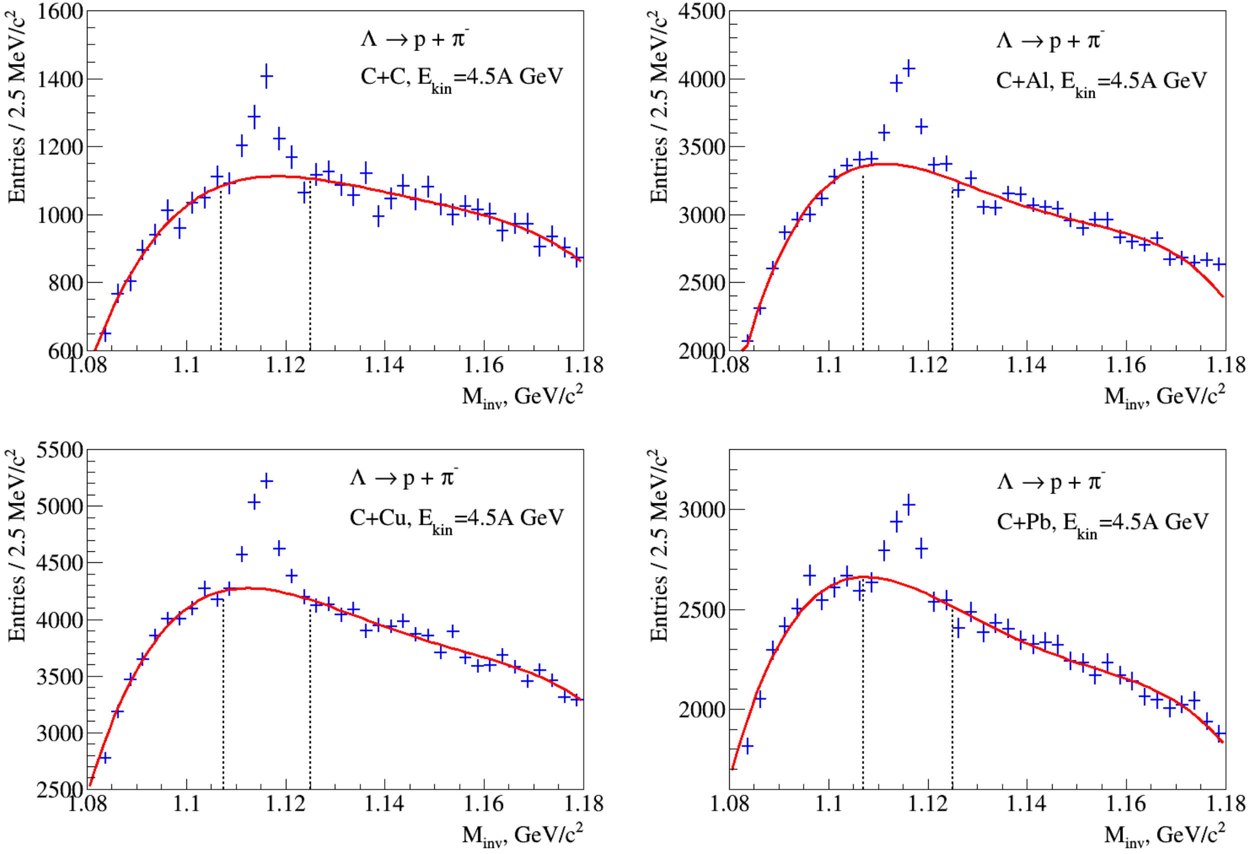
C+C: 4.0M triggers
C+Al: 3.8M triggers
C+Cu: 4.8M triggers
C+Pb: 0.7M triggers

Λ signal width 2.4-3 MeV

sig= hist – bg in
1107.5-1125 MeV/c^2
bg → 4^{th} polynomial

err(stat)=√hist
err(syst)=√(0.5·bg)

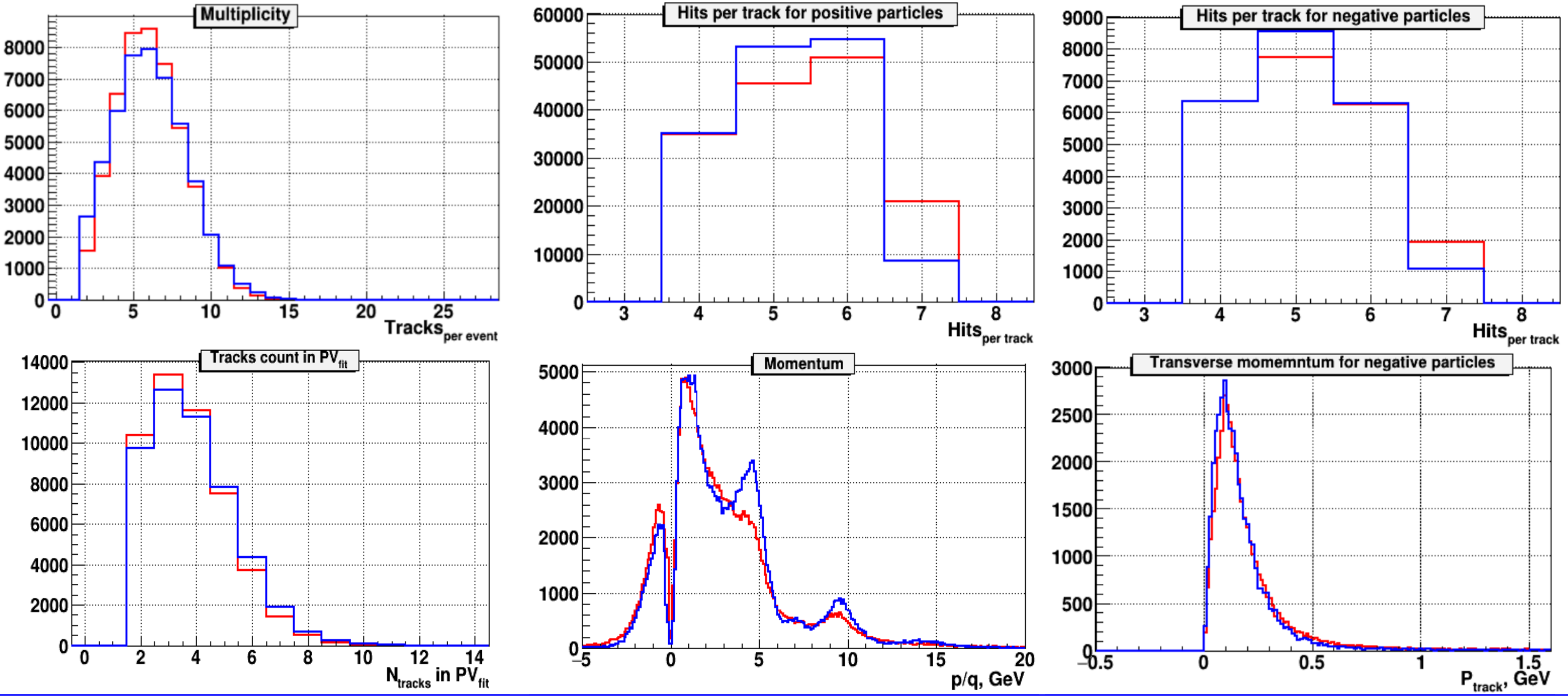
Λ in *C+C*, *Al*, *Cu*, *Pb* interactions (4.5A GeV)



C+C : 2.9M triggers
C+Al: 3.6M triggers
C+Cu: 5.3M triggers
C+Pb: 2.3M triggers

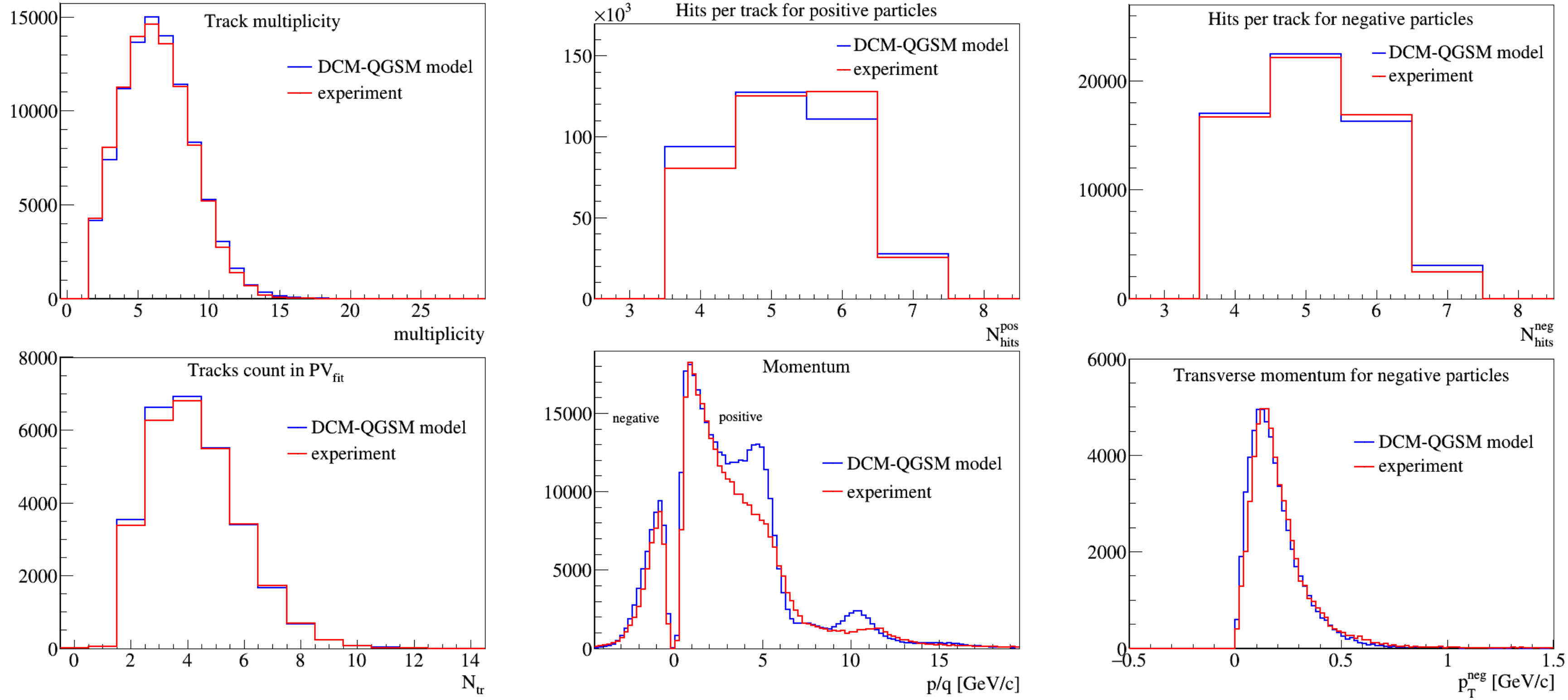
Data vs MC (4A GeV)

Comparison of experimental distributions (red lines) and MC (**DCM-QGSM**) (blue curves) in *C+Cu* interactions



Data vs MC (4.5A GeV)

Comparison of experimental distributions (red lines) and MC (**DCM-QGSM**) (blue curves) in *C+Cu* interaction.



Cross section and yield of Λ hyperon production

Inclusive cross section σ_Λ and yield Y_Λ of Λ hyperon production in $C+C$, $C+Al$, $C+Cu$, $C+Pb$ interactions are calculated in bins of y (p_T) according to the formulae:

$$\sigma_\Lambda(y) = \Sigma_y\, [N_{rec}^{\Lambda}(y,p_T) / (\varepsilon_{rec}(y,p_T)\cdot\varepsilon_{trig}\cdot\varepsilon_{pileup}\cdot L); \qquad Y_\Lambda(y) = \sigma_\Lambda(y) / \sigma_{inel}$$

$$\sigma_\Lambda(p_T) = \Sigma_{pT}\, [N_{rec}^{\Lambda}(y,p_T) / (\varepsilon_{rec}(y,p_T)\cdot\varepsilon_{trig}\cdot\varepsilon_{pileup}\cdot L); \qquad Y_\Lambda(p_T) = \sigma_\Lambda(p_T) / \sigma_{inel}$$

N_{rec}^{Λ}–number of reconstructed Λ hyperons, ε_{rec}–combined efficiency of Λ hyperon reconstruction, ε_{pileup} – beam halo and pile-up suppression factor, ε_{trig}–trigger efficiency, σ_{inel}– cross section for inelastic $C+A$ interactions.

Decomposition of Λ reconstruction efficiency.

Reconstruction efficiency	$\varepsilon_{rec}=\varepsilon_{acc}\cdot\varepsilon_{emb+cuts}$
Λ geometrical acceptance in GEM detectors	$\varepsilon_{acc}=N_{acc}(y,p_T) / N_{gen}(y,p_T)$
Efficiency of reconstruction of embedded Λ after cuts	$\varepsilon_{emb+cuts}=N_{emb+cuts}(y,p_T) /N_{acc}(y,p_T)$

Kinematic range of the measurement:

$0.1<p_T<1.05$ GeV/c
$1.2 <y_{lab}<2.1$ for 4A GeV data
$1.25 <y_{lab}<2.15$ for 4.5A GeV data

→ $0.03 <y^*<0.93$ in nucleon-nucleon c.m.s.

Normalization to inelastic *C+A* cross sections

- Cross section for inelastic *C+C* interactions is taken from the measurement [AngelovCC].
- Cross sections for inelastic *C+Al*, *C+Cu* interactions are taken from the predictions of the DCM-QGSM model which are consistent with the results calculated by the formula:

$\sigma_{inel} = \pi R_0^2 (A_P^{1/3} + A_T^{1/3})^2$, where R_0 = 1.2 fm is an effective nucleon radius, A_P and A_T are atomic numbers of the beam and target nucleus.

- Uncertainty from comparison with the parametrization: $\sigma_{inel} = \pi R_0^2 (A_P^{1/3} + A_T^{1/3} - b)^2$, where R_0 = 1.46 fm and b = 1.21 [AngelovCC] and with cross sections in UrQMD .

Interaction	*C+C*	*C+Al*	*C+Cu*	*C+Pb*
Inelastic cross section, mb	830±50	1260±50	1790±50	3075±50

Reconstructed signals of Λ hyperons

Reconstructed signals of Λ hyperons in bins of y_{lab} and p_T in 4 and 4.5A GeV carbon-target interactions. The first error presents the statistical uncertainty, the second error is systematic.

Target / y interval in lab. frame	y: C	y: Al	y: Cu	y: Pb	Target / pT interval	p_T: C	p_T: Al	p_T: Cu	p_T: Pb
1.2-1.45	225±35±23	279±52±35	610±66±43	133±27±18	0.1-0.3	463±58±38	427±77±52	691±89±60	164±35±23
1.45-1.65	343±41±26	475±61±40	643±73±48	110±28±19	0.3-0.55	380±52±34	538±76±51	787±89±60	159±34±22
1.65-1.85	334±48±31	420±69±46	604±79±54	102±31±20	0.55-0.8	285±40±25	462±61±40	450±70±47	91±27±18
1.85-2.1	284±52±35	371±72±49	375±79±55	111±30±19	0.8-1.05	57±20±13	118±32±21	304±39±25	43±13±9

Target / y inter. in lab. frame	y: C	y: Al	y: Cu	y: Pb	Target / p_T interval	p_T: C	p_T: Al	p_T: Cu	p_T: Pb
1.25-1.5	170±38±25	316±67±46	640±81±55	292±69±47	0.1-0.3	141±58±40	270±91±63	674±103±70	211±79±55
1.5-1.7	248±42±28	555±76±50	635±87±59	304±69±47	0.3-0.55	306±52±34	632±92±63	803±104±71	418±81±56
1.7-1.9	242±48±32	570±84±56	626±93±64	417±70±48	0.55-0.8	239±43±28	549±79±53	698±88±60	312±69±47
1.9-2.15	79±54±37	223±91±62	650±98±67	57±70±49	0.8-1.05	54±24±16	211±48±32	375±55±36	129±43±28

Systematic uncertainties

Systematic error of Λ yield in every p_T and y bin is calculated as a quadratic sum of uncertainties coming from the following sources:

- Systematic errors of the embedding efficiency estimated by embedding the Λ decay products into data samples collected in different run periods (5 run periods per target)
- Systematic errors of the background subtraction under Λ signal in the (p,π^-) invariant mass spectra (polynomial fits)
- Λ yield normalization uncertainty calculated as a quadratic sum of uncertainties of the trigger efficiency, luminosity and inelastic cross section

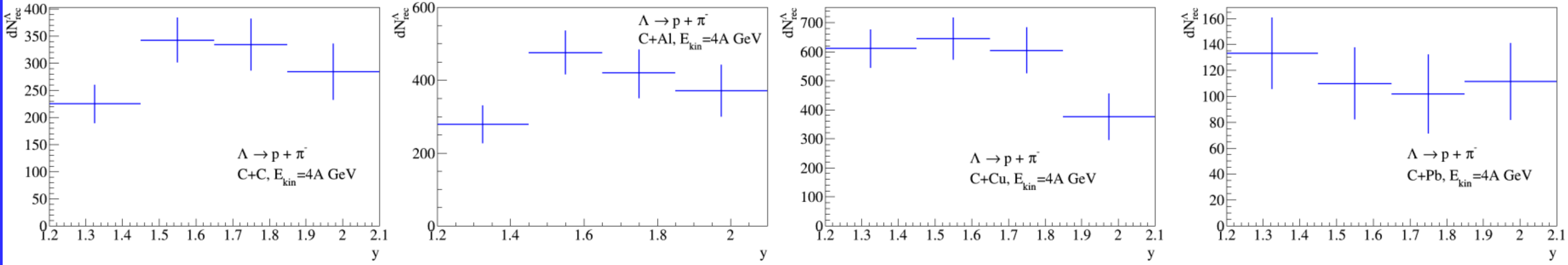
Systematic uncertainty of the Λ yield

Total systematic uncertainty of the Λ yield in y and p_T intervals for 4 and 4.5A GeV data.

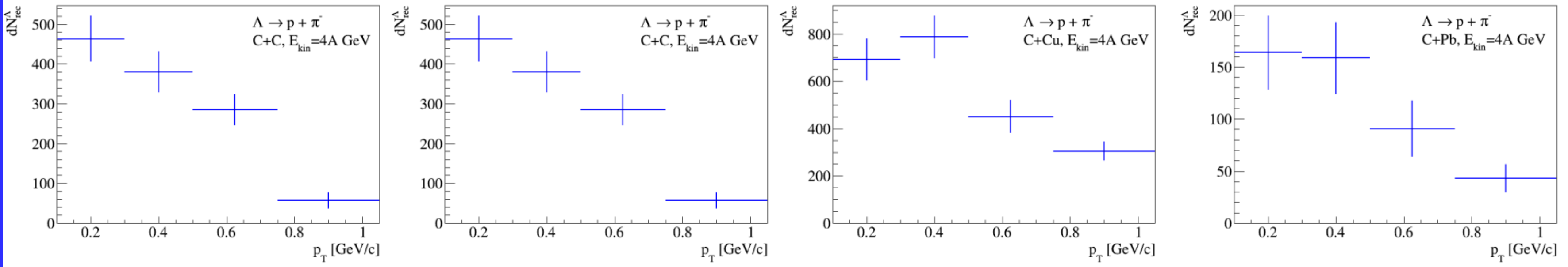
Interval \ Target	*y*				Interval \ Target	p_T			
	C sys%	***Al*** sys%	***Cu*** sys%	***Pb*** sys%		***C*** sys%	***Al*** sys%	***Cu*** sys%	***Pb*** sys%
1.2-1.45	11.4	14.5	8.6	16.8	0.1-0.3	10.0	13.6	10.0	15.8
1.45-1.65	9.3	9.6	8.2	16.4	0.3-0.55	9.7	10.8	7.7	14.3
1.65-1.85	11.0	13.1	10.7	20.1	0.55-0.8	10.5	11.5	11.5	15.3
1.85-2.1	15.0	16.1	18.9	22.3	0.8-1.05	28.9	25.9	23.3	34.5
Normalization	4.9	3.8	3.0	3.0	Normalization	4.9	3.8	3.0	3.0

Interval \ Target	*y*				Interval \ Target	p_T			
	C, sys%	***Al***, sys%	***Cu***, sys%	***Pb***, sys%		***C***, sys%	***Al***, sys%	***Cu***, sys%	***Pb***, sys%
1.25-1.5	15.4	16.3	13.1	16.5	0.1-0.3	24.5	22.8	13.3	23.4
1.5-1.7	13.3	10.4	10.8	15.0	0.3-0.55	12.1	12.4	10.7	14.3
1.7-1.9	14.6	11.9	11.5	12.6	0.55-0.8	11.6	11.3	13.4	16.7
1.9-2.15	27.8	29.0	12.4	29.1	0.8-1.05	40.3	16.4	15.5	22.8
Normalization	4.9	3.8	3.0	3.0	Normalization	4.9	3.8	3.0	3.0

Number of reconstructed Λ hyperons (4A GeV)

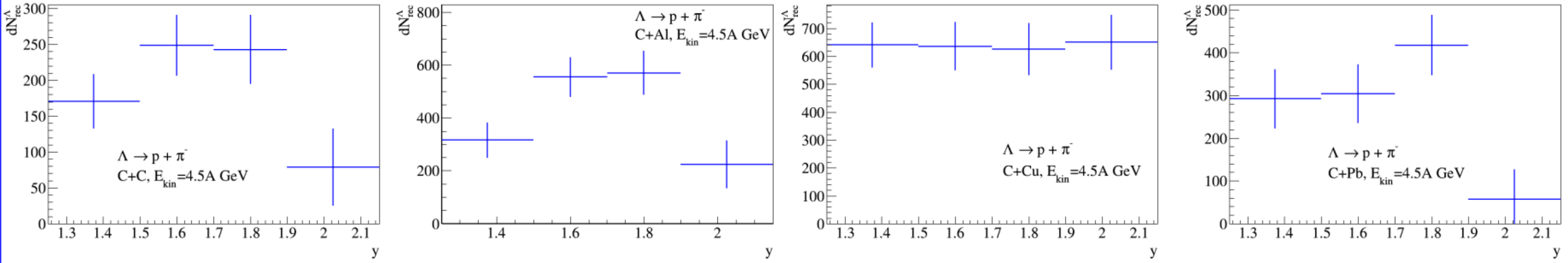


Number of reconstructed Λ hyperons in y_{lab} bins.

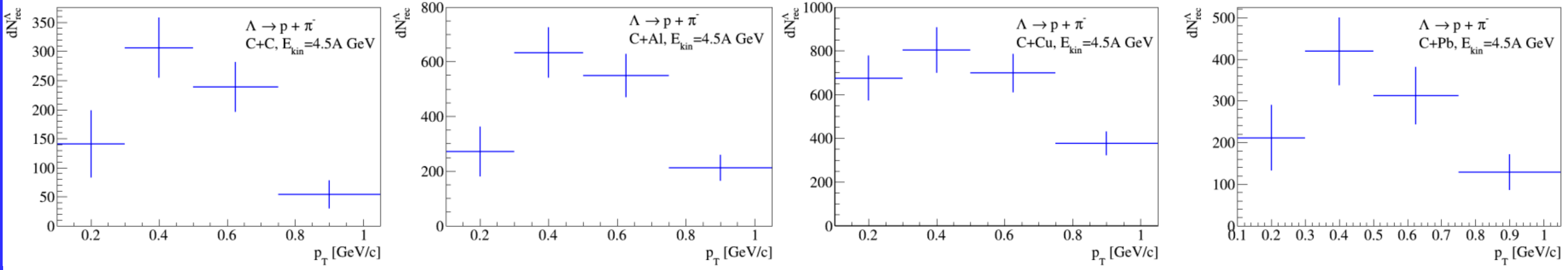


Number of reconstructed Λ hyperons in p_T bins.

Number of reconstructed Λ hyperons (4.5A GeV)

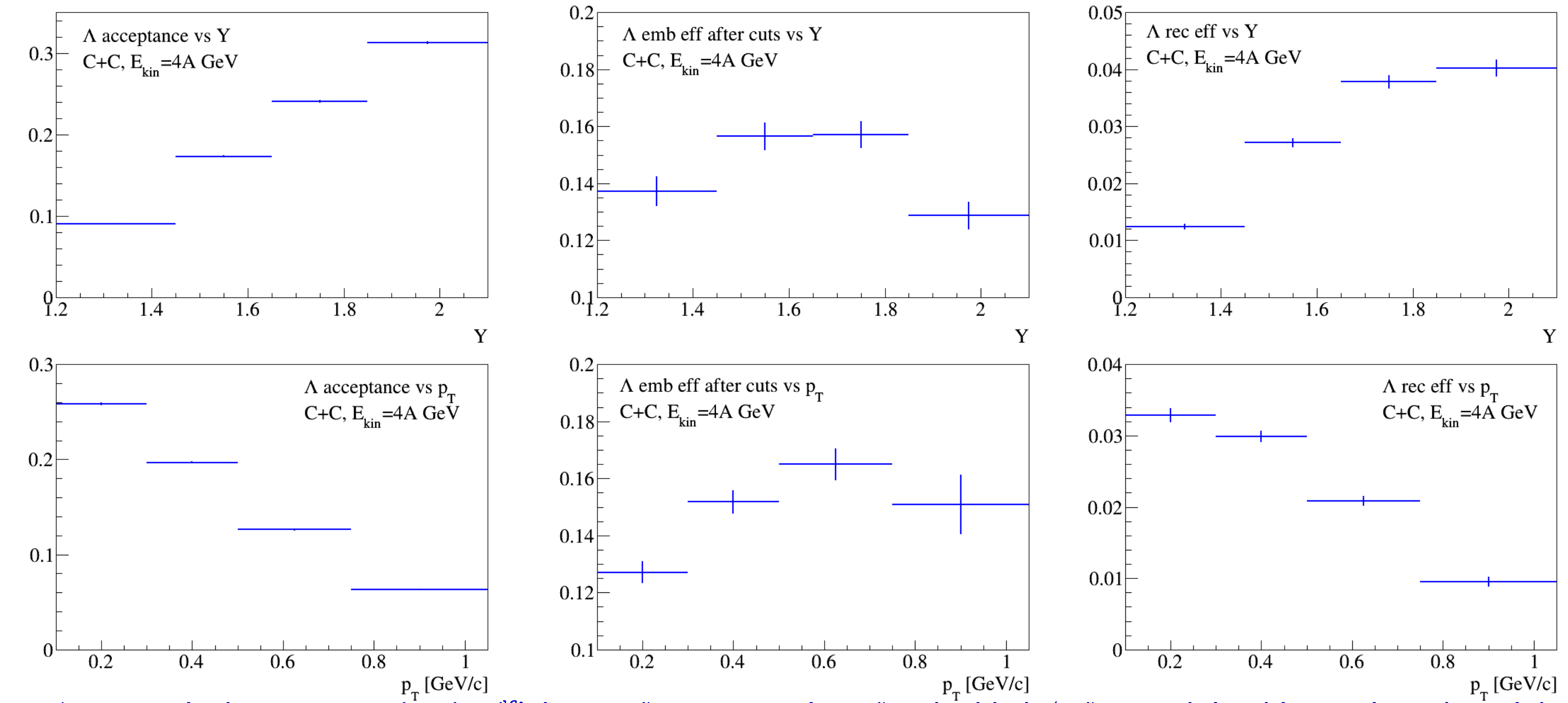


Number of reconstructed Λ hyperons in $\boldsymbol{y_{lab}}$ bins.



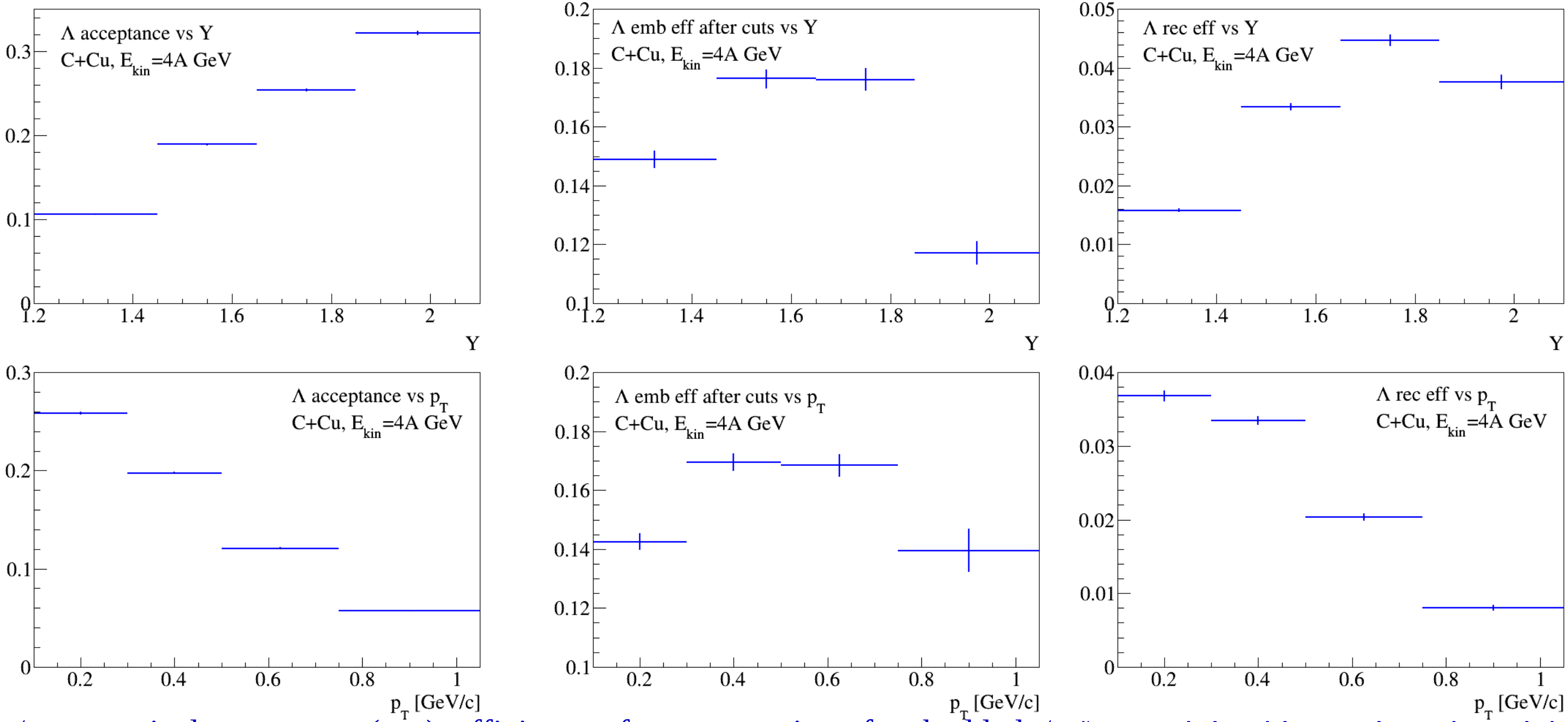
Number of reconstructed Λ hyperons in $\boldsymbol{p_T}$ bins.

Efficiency (*C*+*C*, 4A GeV)



Λ geometrical acceptance (ε_{acc}); efficiency of reconstruction of embedded *Λ* after applying kinematic and spatial cuts ($\varepsilon_{emb+cuts}$) and full reconstruction efficiency (ε_{rec}) in y_{lab} and p_T bins (*C*+*C* @ 4A GeV).

Efficiency (*C+Cu*, 4A GeV)



Λ geometrical acceptance (ε_{acc}); efficiency of reconstruction of embedded *Λ* after applying kinematic and spatial cuts ($\varepsilon_{emb+cuts}$) and full reconstruction efficiency (ε_{rec}) in y_{lab} and p_T bins (*C+Cu* @ 4A GeV).

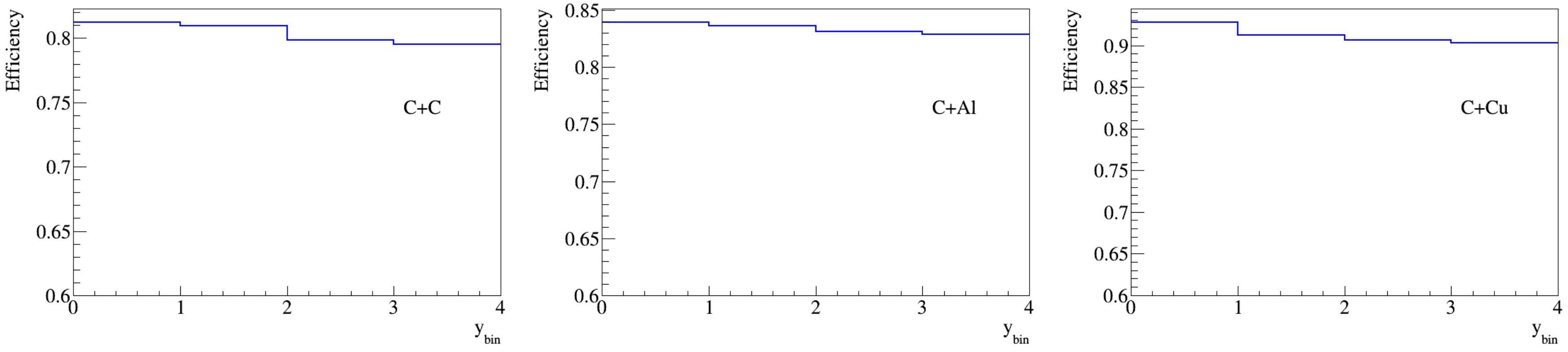
Trigger efficiency (*C+C*, *C+Al*, *C+Cu*, *C+Pb*)

Trigger / Target, 4.0 AGeV	***C***	***Al***	***Cu***	***Pb***
ε_{trig} (BD>=2)	0.80±0.02			
ε_{trig} (BD>=3)		0.866±0.02	0.919±0.02	0.95±0.02

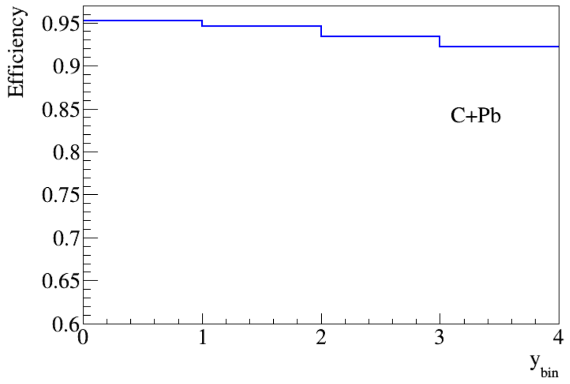
Trigger / Target, 4.5 AGeV	***C***	***Al***	***Cu***	***Pb***
ε_{trig} (BD>=2)	0.80±0.02			
ε_{trig} (BD>=3)		0.834±0.02	0.912±0.02	0.94±0.02

The trigger efficiency was evaluated by a convolution of the GEANT simulation of the trigger BD detector response to DCM-QGSM events with reconstructed Λ hyperons and the GEANT simulation of delta electrons produced by the carbon beam in the *C*, *Al*, *Cu*, *Pb* targets which were found to be the dominant source of delta electrons.

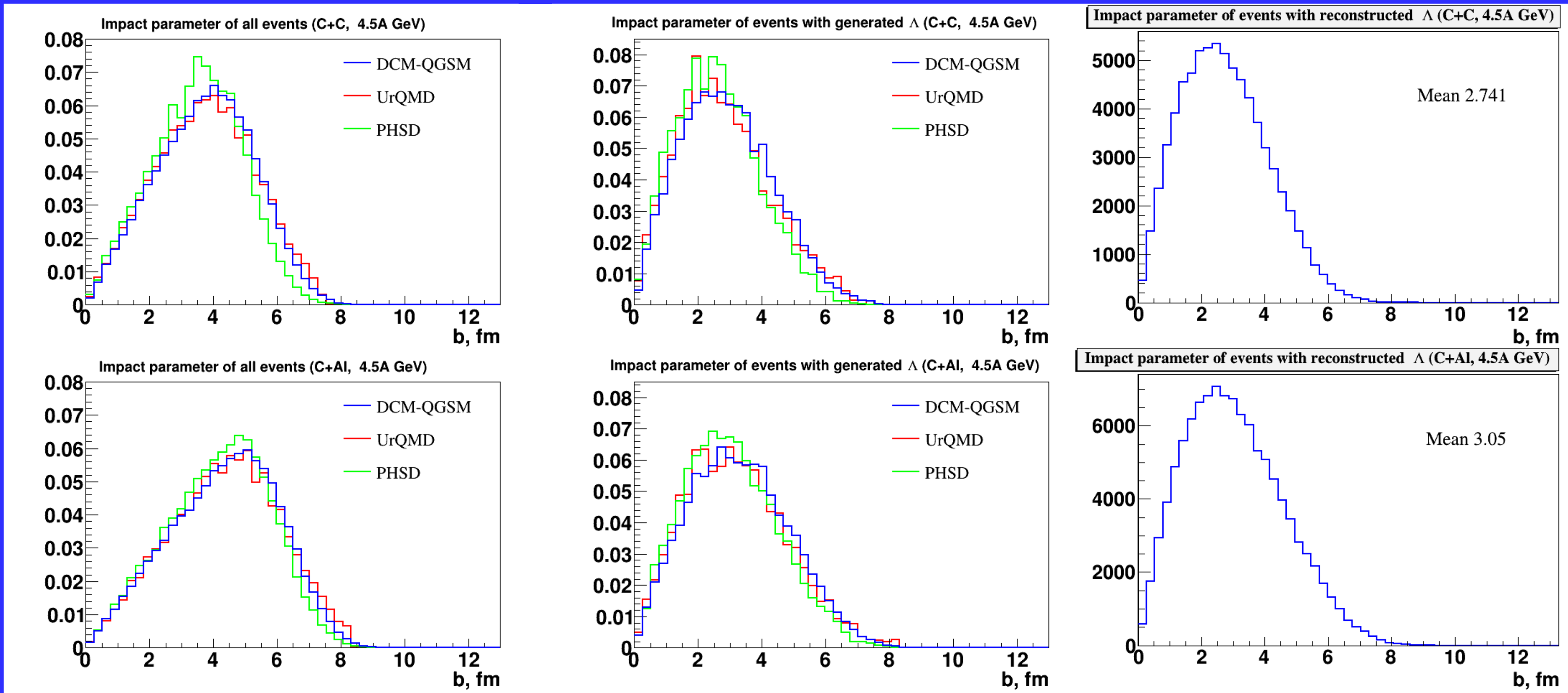
Trigger efficiency (*C+C, C+Al, C+Cu, C+Pb*)



Dependence of the trigger efficiency on *Λ* rapidity for interactions of the carbon beam with the *C, Al, Cu, Pb* targets
→ trigger systematics within ±2%.

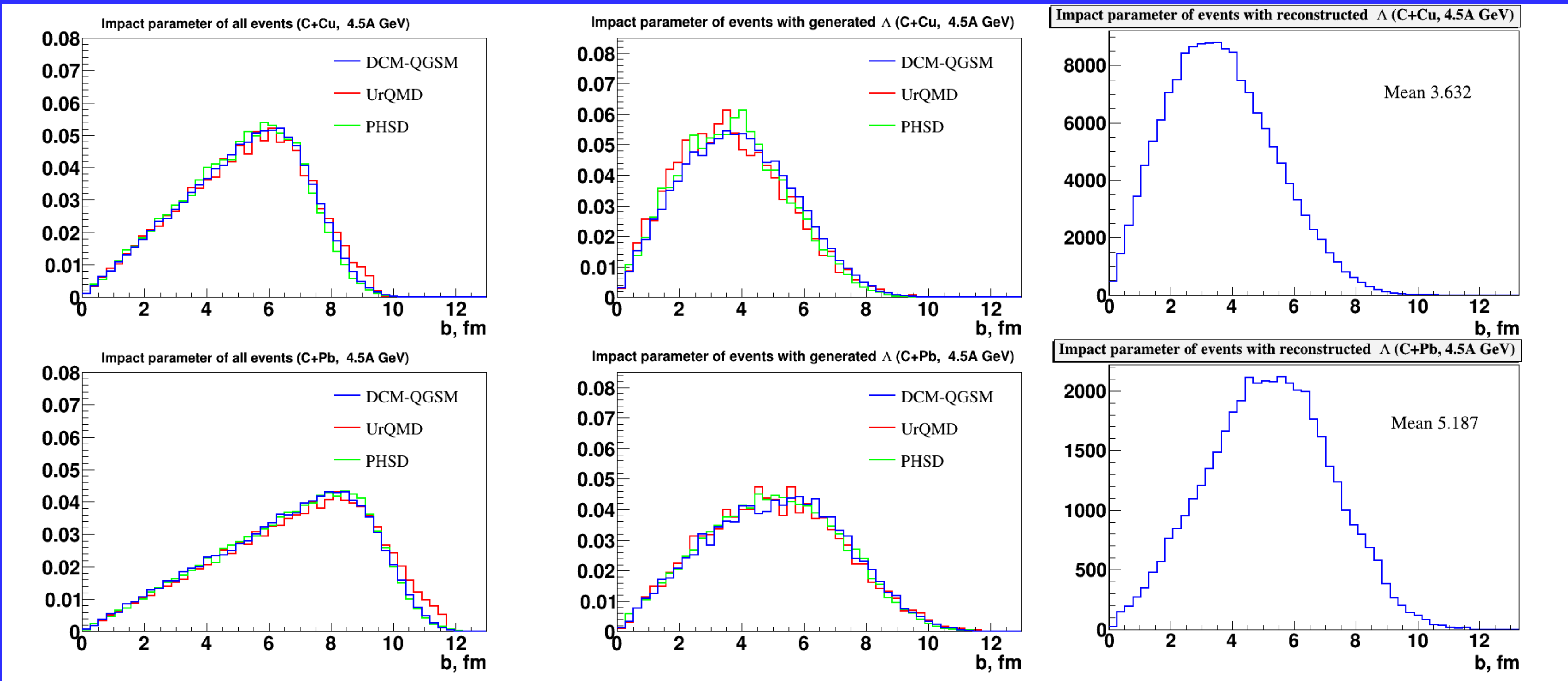


Impact parameter distributions (*C+C, C+Al*)



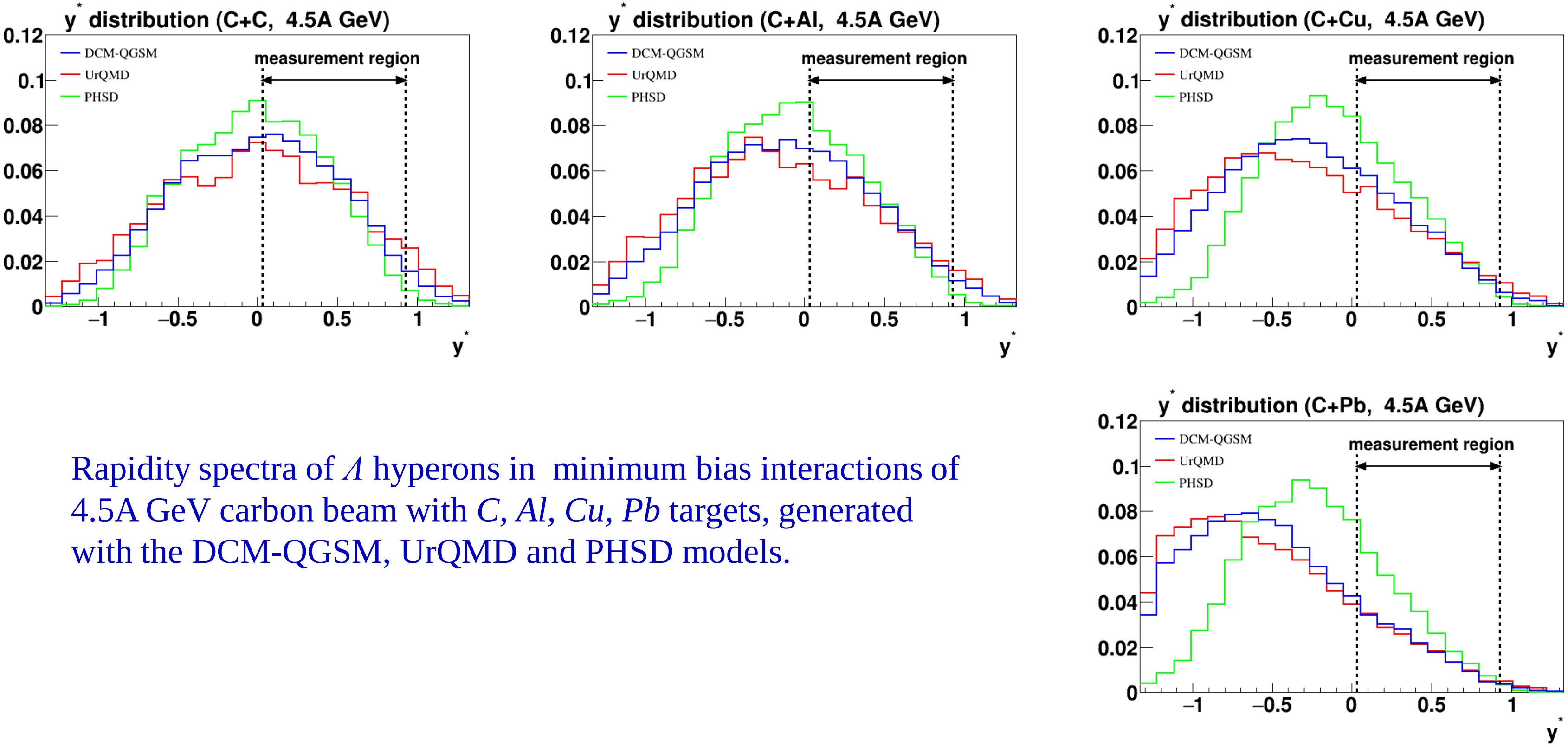
Impact parameter distributions of minimum bias interactions of 4.5A GeV carbon beam with *C, Al* targets, generated with three models (left). Impact parameter distribution of minimum bias events with generated *Λ* hyperons generated with three models (center). Impact parameter distribution of DCM-QGSM minimum bias events with reconstructed *Λ* hyperons (right).

Impact parameter distributions (*C+Cu*, *C+Pb*)



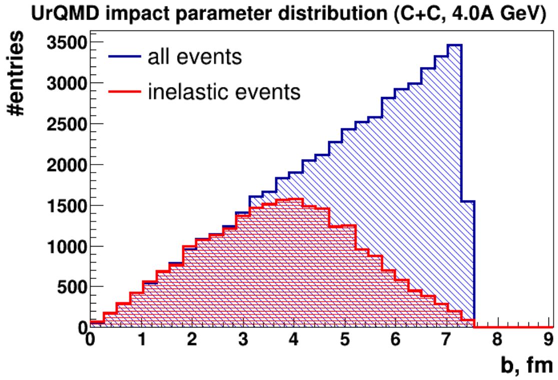
Impact parameter distributions of minimum bias interactions of 4.5A GeV carbon beam with *Cu*, *Pb* targets, generated with three models (left). Impact parameter distribution of minimum bias events with generated *Λ* hyperons generated with three models (center). Impact parameter distribution of DCM-QGSM minimum bias events with reconstructed *Λ* hyperons (right).

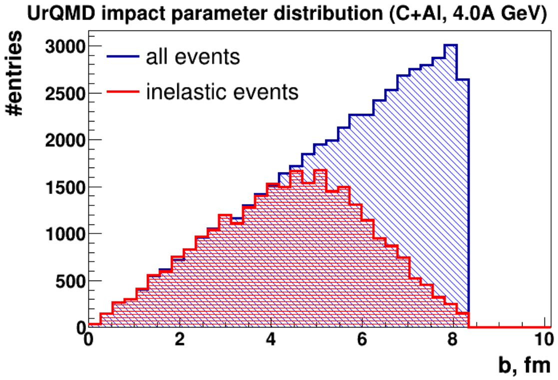
Rapidity spectra: comparison of models

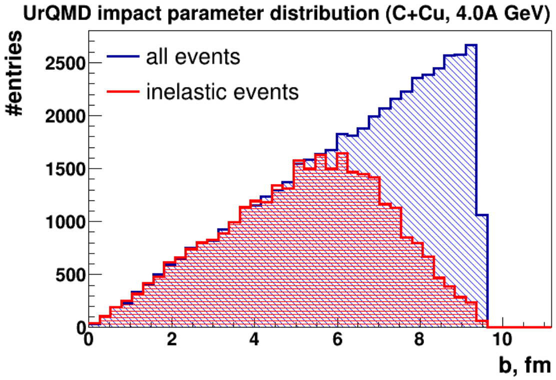


Rapidity spectra of *Λ* hyperons in minimum bias interactions of 4.5A GeV carbon beam with *C*, *Al*, *Cu*, *Pb* targets, generated with the DCM-QGSM, UrQMD and PHSD models.

UrQMD impact parameter distributions





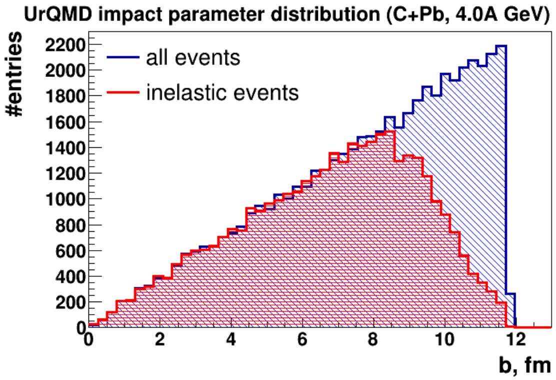


Impact parameter distributions in min bias interactions of 4.5A GeV carbon beam with *C*, *Al*, *Cu*, *Pb* targets, generated with UrQMD model: all interactions vs inelastic interactions

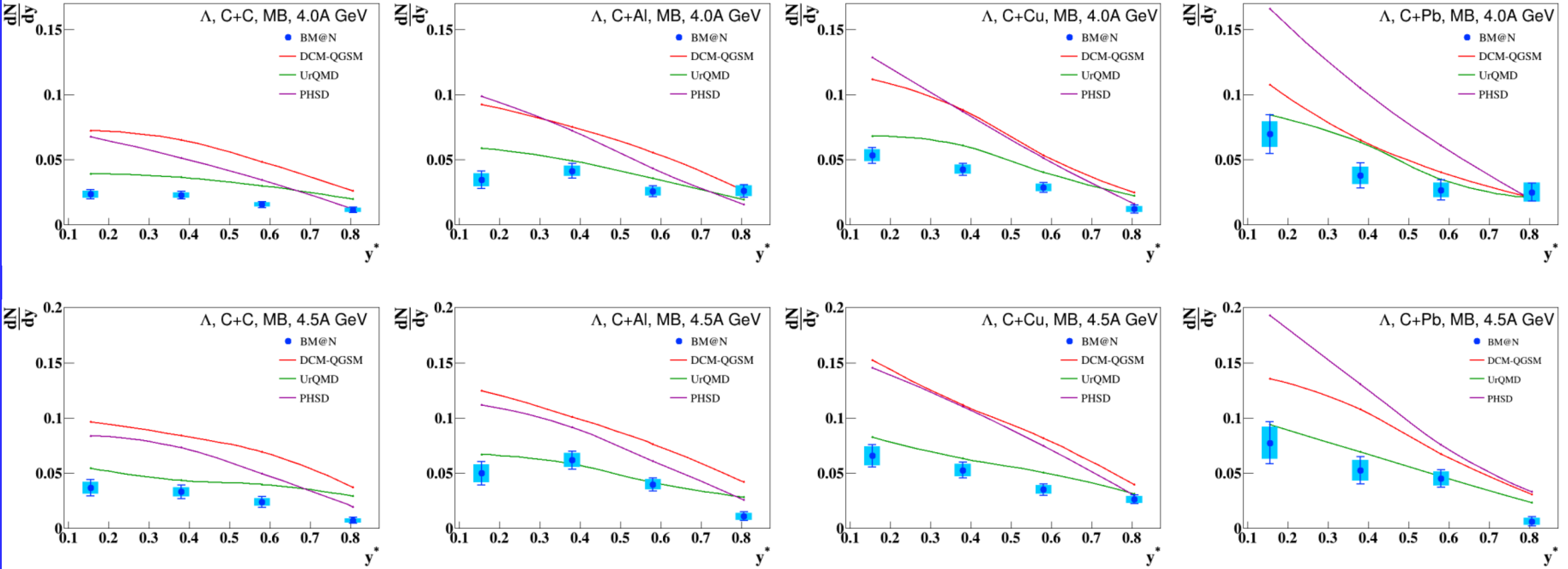
- In Preliminary *Λ* yields from UrQMD were normalized to all interactions

→ now normalize *Λ* yields from UrQMD to inelastic interactions

→ *Λ* yields from UrQMD increased by 1.5 – 2.0

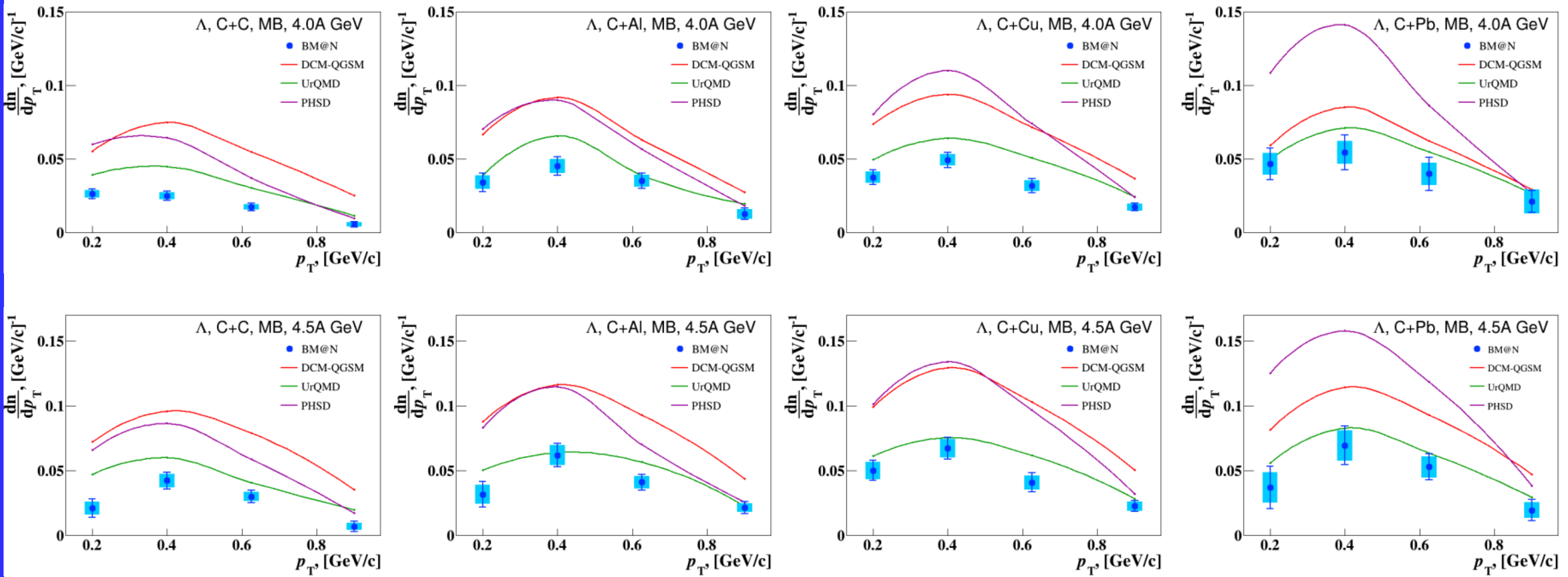


Reconstructed rapidity spectra of Λ hyperons



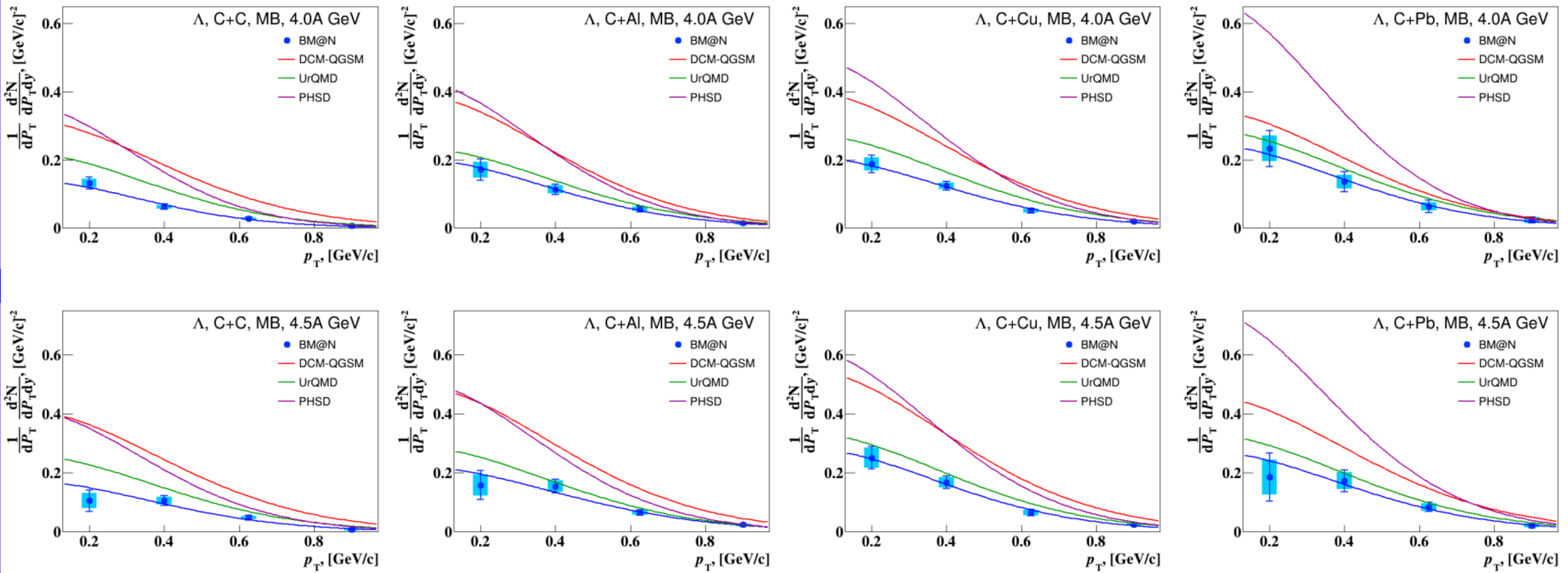
Reconstructed rapidity *y** spectra of Λ hyperons in minimum bias *C+C, C+Al, C+Cu, C+Pb* interactions at 4 and 4.5A GeV carbon beam energy (blue crosses). Predictions of the DCM-QGSM, UrQMD and PHSD models are shown as red, green and magenta lines.

Reconstructed p_T spectra of Λ hyperons



Reconstructed transverse momentum p_T spectra of Λ hyperons in minimum bias *C+C, C+Al, C+Cu, C+Pb* interactions at 4 and 4.5A GeV carbon beam energy (blue crosses). Predictions of the DCM-QGSM, UrQMD and PHSD models are shown as red, green and magenta lines.

Invariant p_T spectra of Λ hyperons



Invariant transverse momentum p_T spectra of Λ hyperons produced in minimum bias *C+C, C+Al, C+Cu, C+Pb* interactions at 4 and 4.5A GeV carbon beam energy (blue crosses). The error bars represent the statistical errors, the blue boxes show the systematic errors. Predictions of the DCM-QGSM, UrQMD and PHSD models are shown as red, green and magenta lines.

Inverse slope parameter T_0

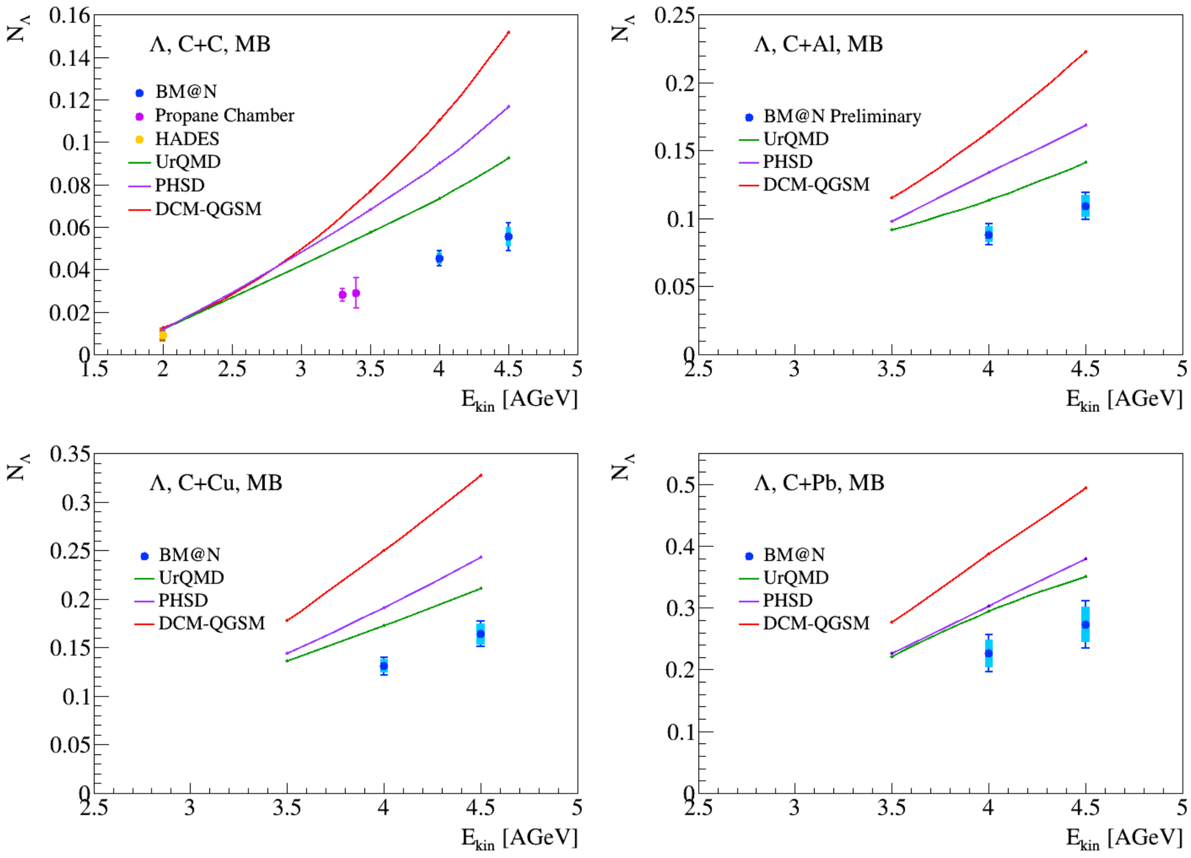
$1/p_T \cdot d^2N/dp_T dy = N \cdot exp(-(m_T - m_\Lambda)/T_0)$, where $m_T = \sqrt{(m_\Lambda^2 + p_T^2)}$ is the transverse mass

Inverse slope parameter extracted from the fit of the p_T spectra for 4 and 4.5A GeV.

4.0 AGeV	T_0, MeV (*C+C*)	T_0, MeV (*C+Al*)	T_0, MeV (*C+Cu*)	T_0, MeV (*C+Pb*)
Experiment χ^2 / ndf	95 ± 11 ± 9 1.61/2	119± 15 ± 12 0.20/2	125 ± 11 ± 9 1.27/2	130 ± 25 ± 21 0.36/2
DCM-QGSM	126	120	133	130
UrQMD	107	128	133	136
PHSD	87	100	105	98

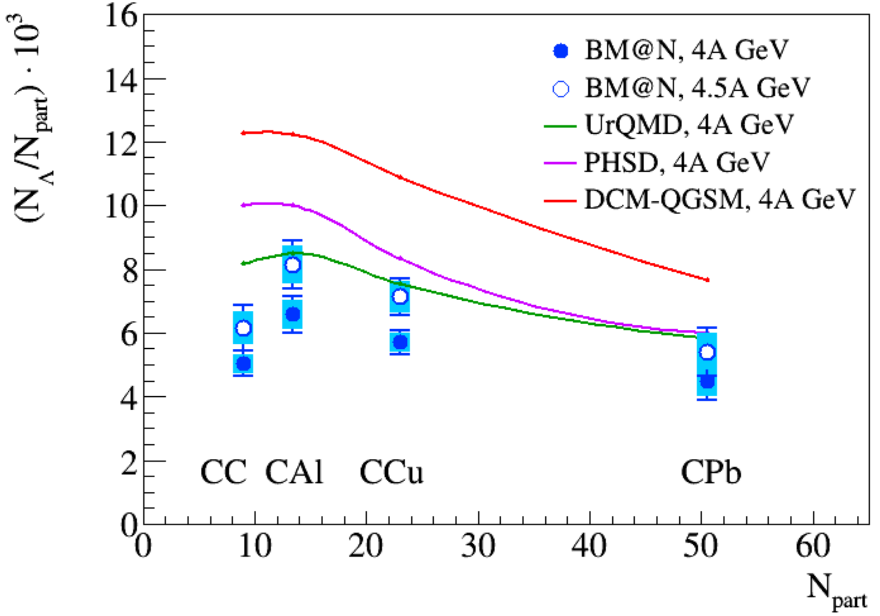
4.5 AGeV	T_0, MeV (*C+C*)	T_0, MeV (*C+Al*)	T_0, MeV (*C+Cu*)	T_0, MeV (*C+Pb*)
Experiment χ^2 / ndf	114 ± 16 ± 12 3.07/2	137 ± 19 ± 15 1.49/2	122 ± 13 ± 11 1.30/2	129 ± 24 ± 19 0.77/2
DCM-QGSM	132	133	135	142
UrQMD	122	128	130	134
PHSD	101	106	109	108

Energy dependence of Λ yields: data vs models



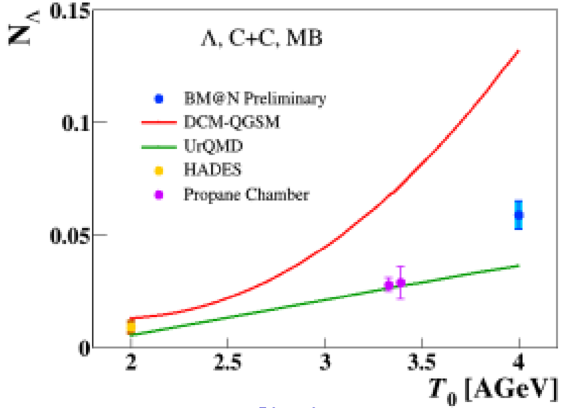
Energy dependence of Λ yields measured in BM@N *C+C*, *C+Al*, *C+Cu*, *C+Pb* minimum bias interactions. The error bars represent the statistical errors, the blue boxes show the systematic errors. The predictions of the DCM-QGSM, UrQMD and PHSD models are shown as colored lines.

N_{Λ} / N_{part} ratio: data vs models

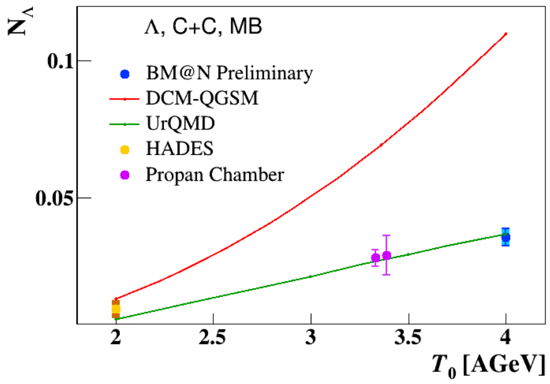


Ratios of the Λ hyperon yields to the number of nucleons-participants measured in BM@N carbon-nucleus interactions at 4 and 4.5A GeV. The error bars represent the statistical errors, the blue boxes show the systematic errors. The predictions of the DCM-QGSM, UrQMD and PHSD models are shown as colored lines.

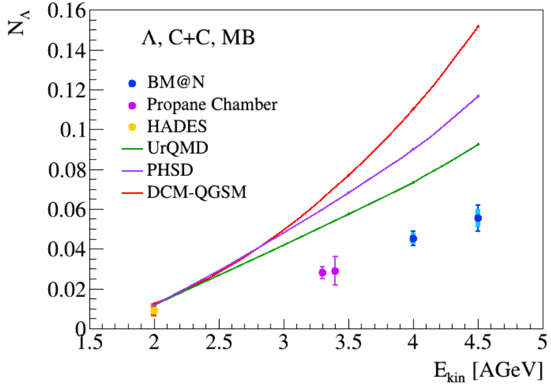
Corrections to Preliminary at 4A GeV



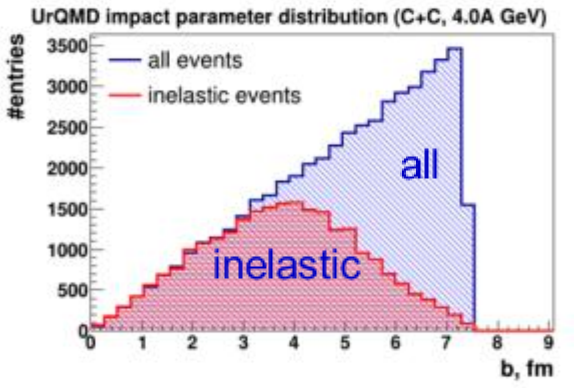
Preliminary June 2019



QM 2019



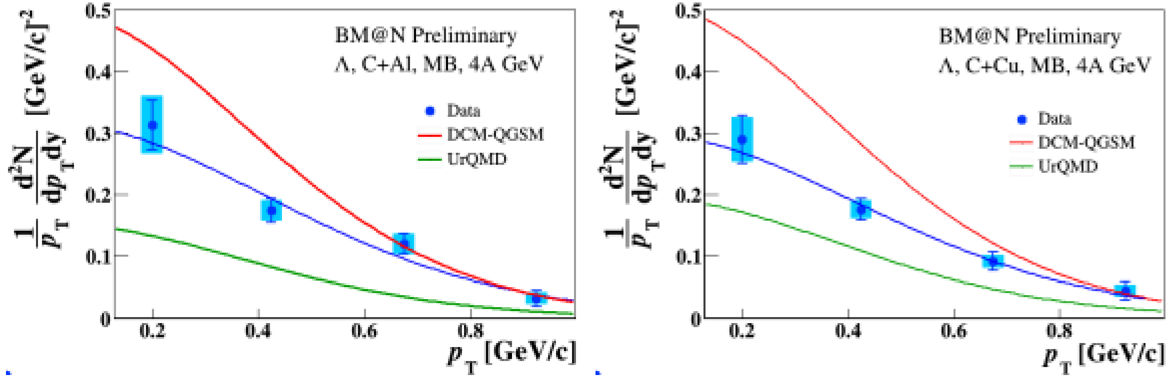
Present



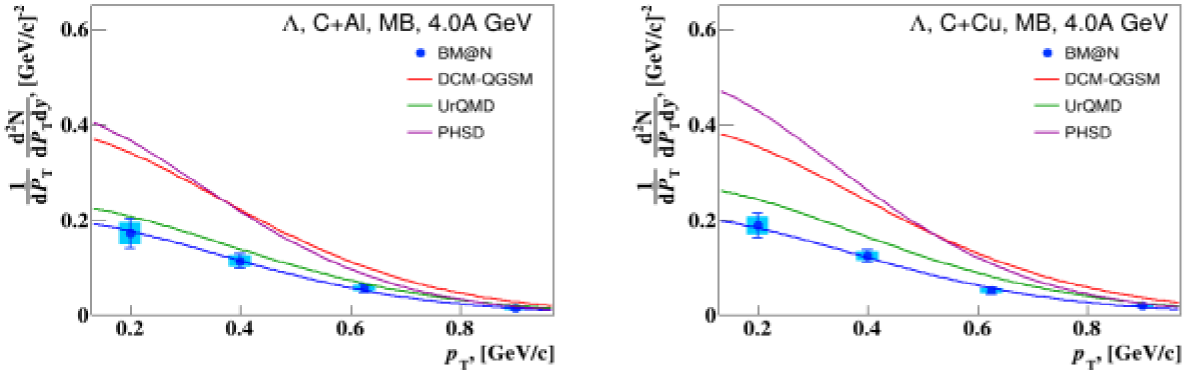
- ✓ Correct technical error in *Λ* embedding efficiency calculation
  → number of all GEM hits in event <200
- ✓ Exclude poor runs with low *Λ* rate: < 0.5·<N_Λ>
  → correlated with GEM hardware problems
  C+C: 4.57M triggers → 3.98M triggers
- ✓ Correct trigger efficiency for events with *Λ*
  C+C: 0.906 → 0.80
- ✓ Now UrQMD yield normalized to inelastic interactions

4A GeV QGSM prediction: LAQGSM→DCM-SMM

Corrections to Preliminary at 4A GeV



Results after corrections



Correct error in Λ embedding efficiency calculation

Exclude poor runs with low Λ rate: $< 0.5\cdot<N_\Lambda>$
C+Al: 5.35M → 3.81M triggers
C+Cu: 5.31M → 4.77M triggers

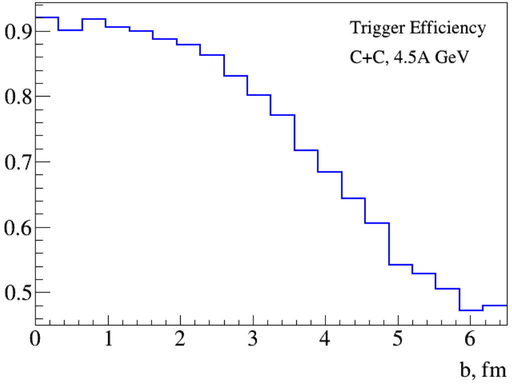
Correct trigger efficiency for events with Λ
C+Al: 0.94 → 0.87

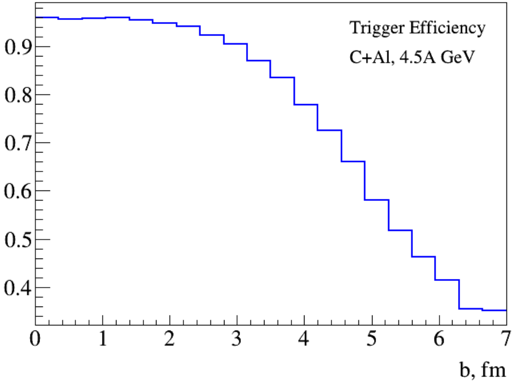
Summary

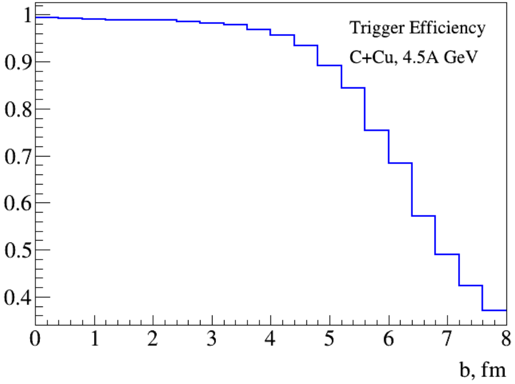
- Production of Λ hyperons in interactions of the carbon beam with *C*, *Al*, *Cu*, *Pb* targets was studied. The analysis procedure is described including details of the Λ hyperon reconstruction, efficiency and systematic uncertainty evaluation.
- First physics results are presented on Λ hyperon yield and cross sections in minimum bias carbon-nucleus interactions at the beam kinetic energies of 4 and 4.5A GeV.
- The results are compared with models of nucleus-nucleus interactions and with the results of other experiments studied carbon-nucleus interactions at lower energies.

Thank you for attention!

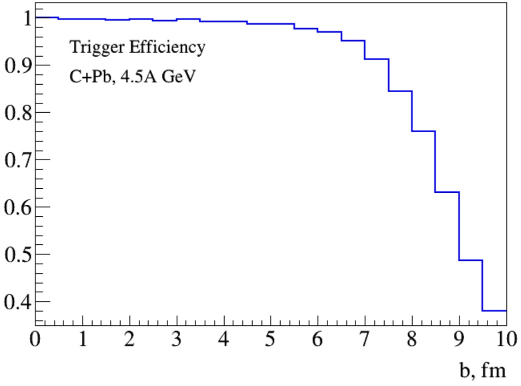
Trigger efficiency (*C+C*, *C+Al*, *C+Cu*, *C+Pb*)





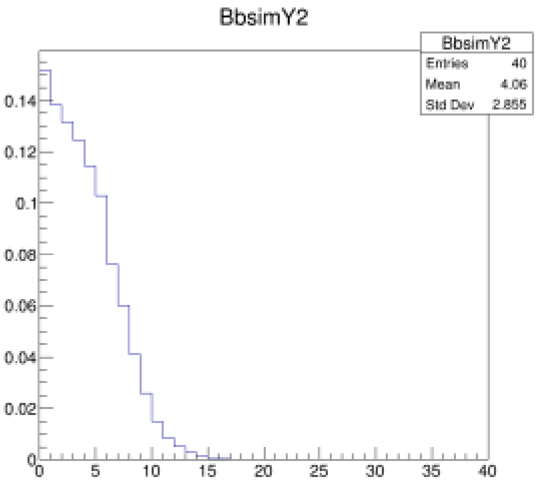


Dependence of the trigger efficiency on the collision impact parameter for interactions of the carbon beam with the *C*, *Al*, *Cu*, *Pb* targets.



Trigger efficiency from BD simulation

BD hits in DCM-QGSM *Λ* events | BD hits from delta electrons | Convolution of BD hits



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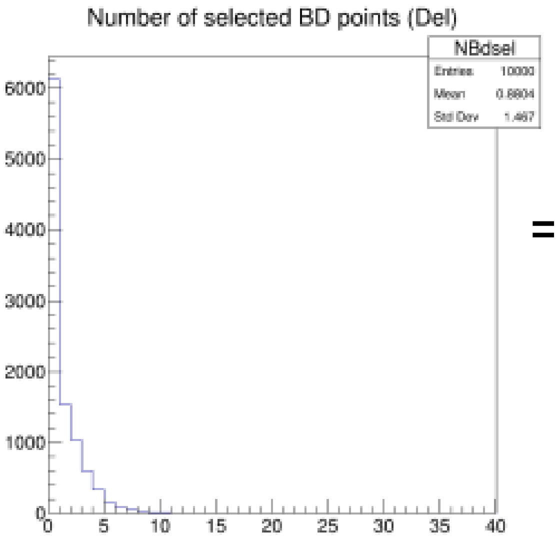

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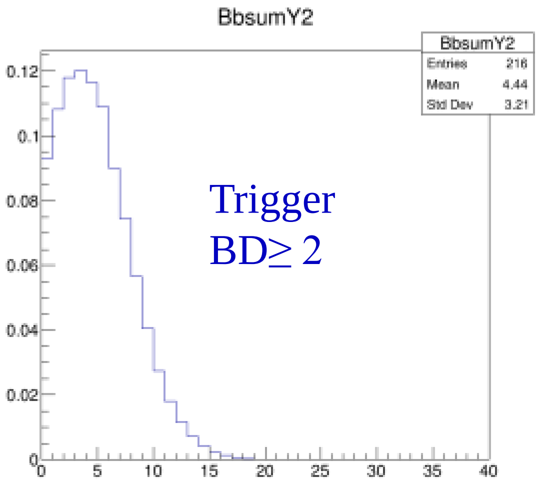
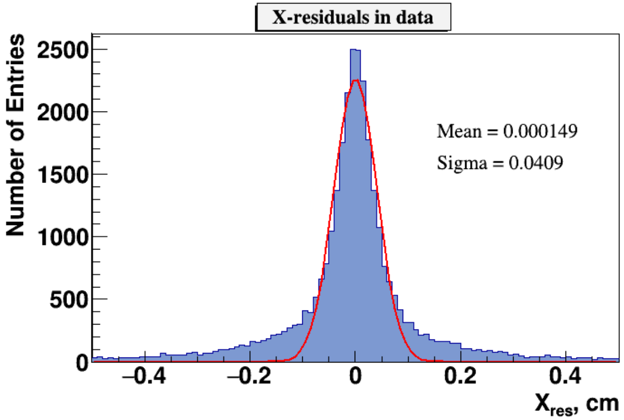
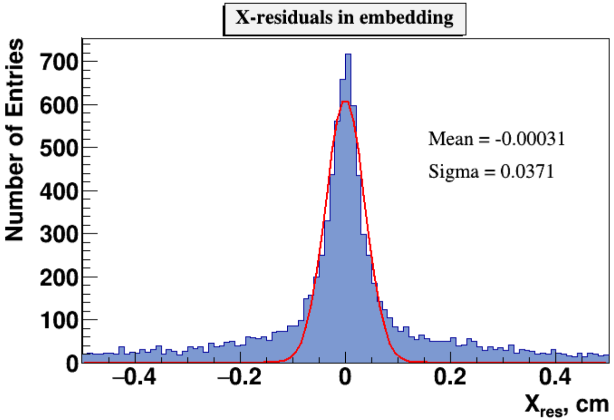
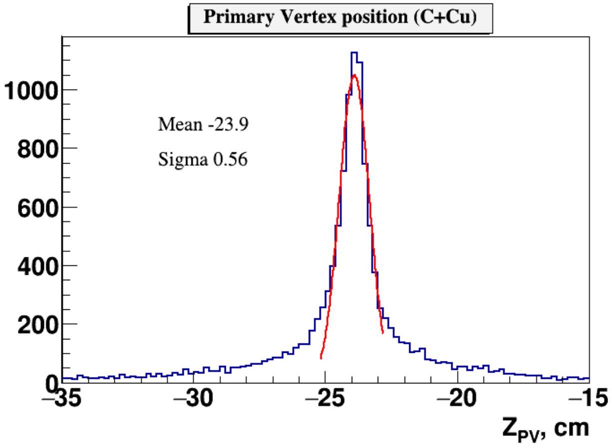


Evaluation of trigger efficiency for *C*+*C* min bias events.

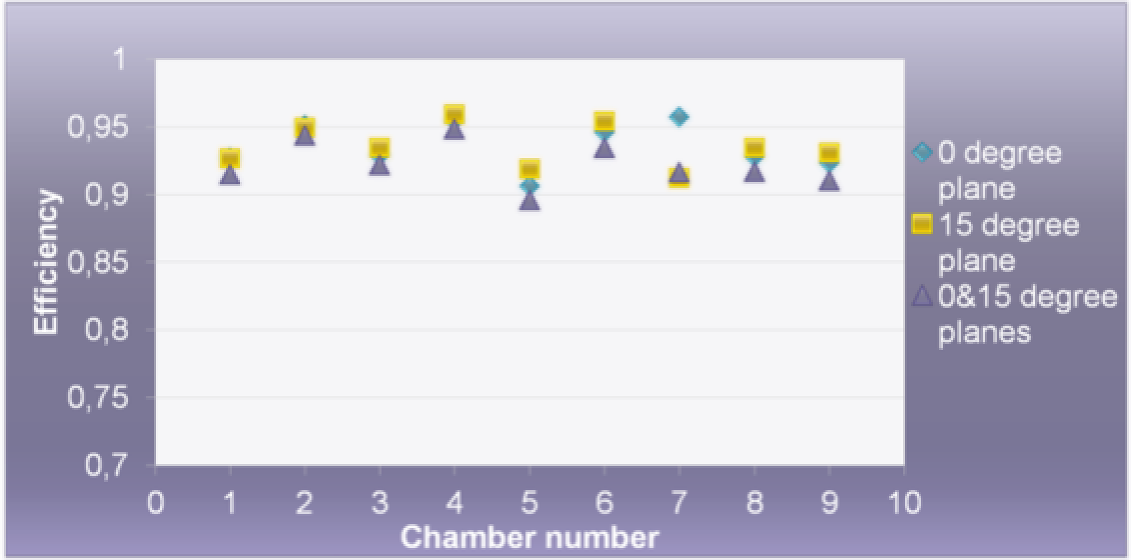
Control plots: residuals, Z_{vertex}

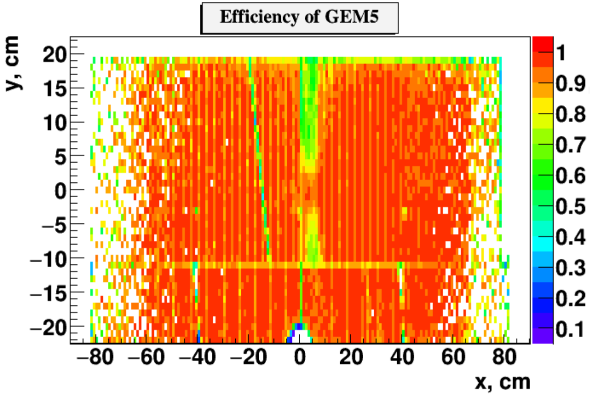






GEM plane detection efficiency





Λ cross section and yields (4A GeV)

Extrapolation factors to the full kinematic range, reconstruction efficiencies, Λ hyperon yields and cross sections for 4A GeV data. The first error given is statistical, the second error is systematic.

4.0A GeV	***C***	***Al***	***Cu***	***Pb***
DCM-QGSM URQMD extrap. factor (average)	2.76	3.08	4.23	6.17
Efficiency in $0.1<p_T<1.05$ GeV/c, $1.2<y_{lab}<2.1$	0.027	0.027	0.024	0.021
Yields in $0.1<p_T<1.05$ GeV/c, $1.2<y_{lab}<2.1$	0.0164±0.0013±0.0010	0.0286±0.0025±0.0020	0.0307±0.0020±0.0016	0.0366±0.0048±0.0036
Yields in the full kin. range N_{part} DCM-QGSM	0.0453±0.0036±0.0027 9	0.0882±0.0077±0.0060 13.4	0.131±0.009±0.007 23	0.226±0.030±0.023 50.5
Λ cross section in min. bias interactions, mb	37.6 ± 3.0 ± 2.3	111.2 ± 9.7 ± 7.6	234 ± 16 ± 12	695 ± 91 ± 72
Inverse slope parameter, MeV / χ^2 / ndf	95 ± 11 ± 9 1.61/2	119 ± 15 ± 12 0.20/2	125 ± 11 ± 9 1.27/2	125 ± 25 ± 21 0.36/2

Λ cross section and yields (4.5A GeV)

Extrapolation factors to the full kinematic range, reconstruction efficiencies, Λ hyperon yields and cross sections for 4.5A GeV data. The first error given is statistical, the second error is systematic.

4.5A GeV	***C***	***Al***	***Cu***	***Pb***
DCM-QGSM URQMD extrap. factor (average)	2.48	3.07	3.98	6.74
Efficiency in $0.1<p_T<1.05$ GeV/c, $1.25<y_{lab}<2.15$	0.020	0.021	0.016	0.014
Yields in $0.1<p_T<1.05$ GeV/c, $1.25<y_{lab}<2.15$	0.0224±0.0026±0.0019	0.0355±0.0034±0.0026	0.0406±0.0032±0.0026	0.040±0.0057±0.0043
Yields in the full kin. range N_{part} DCM-QGSM	0.0554±0.0064±0.0047 9	0.109±0.010±0.008 13.4	0.164±0.013±0.011 23	0.273±0.038±0.029 50.5
Λ cross section in min. bias interactions, mb	46.0 ± 5.3 ± 3.9	137 ± 13 ± 10	293 ± 23 ± 19	839 ± 117 ± 90
Inverse slope parameter, MeV / χ^2 / ndf	114 ± 16 ± 12 3.07/2	137 ± 19 ± 15 1.49/2	122 ± 13 ± 11 1.30/2	129 ± 24 ± 19 0.77/2

Λ hyperon yields (C+C): data vs models

Λ hyperon yields and yields normalized to the number of nucleons-participants. The first error is statistical, the second error is systematic. Predictions of the DCM-QGSM, UrQMD and PHSD models are shown for carbon-carbon interactions at different beam energies.

C+C	**4.5 AGeV**	**4.0 AGeV**	**3.5 AGeV**	**2.0 AGeV**
BM@N yield Yield normal to N_{part}	0.0554±0.0064±0.0047 / 9 $(6.16\pm0.71\pm0.52)\cdot10^{-3}$	0.0453±0.0036±0.0027 $(5.03\pm0.40\pm0.30)\cdot10^{-3}$		
DCM-QGSM DCM-QGSM / N_{part}	0.1518 $16.86\cdot10^{-3}$	0.1103 $12.26\cdot10^{-3}$	0.0771 $8.57\cdot10^{-3}$	0.0125 $1.39\cdot10^{-3}$
UrQMD yield UrQMD / N_{part}	0.0927 $10.3\cdot10^{-3}$	0.0736 $8.17\cdot10^{-3}$	0.0577 $6.41\cdot10^{-3}$	0.0118 $1.31\cdot10^{-3}$
PHSD yield PHSD / N_{part}	0.1167 $12.97\cdot10^{-3}$	0.09 $10.0\cdot10^{-3}$	0.0684 $7.6\cdot10^{-3}$	0.0119 $1.32\cdot10^{-3}$
Other Experiments			$(2.89\pm0.72)\cdot10^{-2}$ (3.36 AGeV) $(2.8\pm0.3)\cdot10^{-2}$ (3.36 AGeV) Propane Chamber	$(0.92\pm0.12+0.34-0.17)$ $\cdot10^{-2}$ HADES

Λ hyperon yields ($C+Al$, $C+Cu$): data vs models

C+Al	**4.5 AGeV**	**4.0 AGeV**	**3.5 AGeV**
BM@N yield Yield normal to N_{part}	0.109±0.010±0.008 / 13.4 $(8.13\pm0.75\pm0.60)\cdot10^{-3}$	0.0882±0.0077±0.0060 $(6.58\pm0.57\pm0.45)\cdot10^{-3}$	
DCM-QGSM QGSM / N_{part}	0.2231 $16.65\cdot10^{-3}$	0.164 $12.24\cdot10^{-3}$	0.1153 $8.61\cdot10^{-3}$
UrQMD yield UrQMD / N_{part}	0.1414 $10.55\cdot10^{-3}$	0.1138 $8.49\cdot10^{-3}$	0.092 $6.86\cdot10^{-3}$
PHSD yield PHSD / N_{part}	0.1685 $12.58\cdot10^{-3}$	0.1339 $9.99\cdot10^{-3}$	0.0983 $7.34\cdot10^{-3}$

C+Cu	**4.5 AGeV**	**4.0 AGeV**	**3.5 AGeV**
BM@N yield Yield normal to N_{part}	0.164±0.013±0.011 / 23 $(7.13\pm0.56\pm0.48)\cdot10^{-3}$	0.131±0.009±0.007 (5.70±0.39±0.30)·10-3	
DCM-QGSM QGSM / N_{part}	0.3279 $14.26\cdot10^{-3}$	0.2503 $10.88\cdot10^{-3}$	0.1782 $7.75\cdot10^{-3}$
UrQMD yield UrQMD / N_{part}	0.2108 $9.16\cdot10^{-3}$	0.1732 $7.53\cdot10^{-3}$	0.1367 $5.94\cdot10^{-3}$
PHSD yield PHSD / N_{part}	0.2433 $10.58\cdot10^{-3}$	0.1914 $8.32\cdot10^{-3}$	0.1445 $6.28\cdot10^{-3}$

Λ hyperon yields (*C+Pb*)

C+Pb	4.5 AGeV	4.0 AGeV	3.5 AGeV
BM@N yield Yield normal to N_{part}	0.273±0.038±0.029 / 50.5 $(5.41\pm0.75\pm0.57)\cdot10^{-3}$	0.226±0.030±0.023 $(4.48\pm0.59\pm0.46)\cdot10^{-3}$	
DCM-QGSM QGSM / N_{part}	0.4937 $9.78\cdot10^{-3}$	0.3872 $7.67\cdot10^{-3}$	0.277 $5.48\cdot10^{-3}$
UrQMD yield UrQMD / N_{part}	0.3504 $6.94\cdot10^{-3}$	0.2947 $5.84\cdot10^{-3}$	0.2215 $4.39\cdot10^{-3}$
PHSD yield PHSD / N_{part}	0.3798 $7.52\cdot10^{-3}$	0.3033 $6.01\cdot10^{-3}$	0.2261 $4.48\cdot10^{-3}$