XXIV International Baldin Seminar
on High Energy Physics Problems “Relativistic Nuclear Physics
and Quantum Chromodynamics”

Sigma-hyperons in nuclear collisions at energy of few GeV/c

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Outline

- Motivation of sigma-hyperon studying in nuclear collisions at low energies
- Model predictions for hyperons
- Status of sigma reconstruction from experimental data
- Conclusion

Motivation

- Nuclear matter at high baryon densities and average temperatures is the area to search for new phase transition and new phenomena
- It is necessary to study strangeness to have more completely observation of nuclear matter
- In baryonic matter kaons are preferably born with hyperons, but there are not enough information about hyperon’s borning
- Experimental data for hyperons at energy of few GeV/c is not sufficient

Motivation

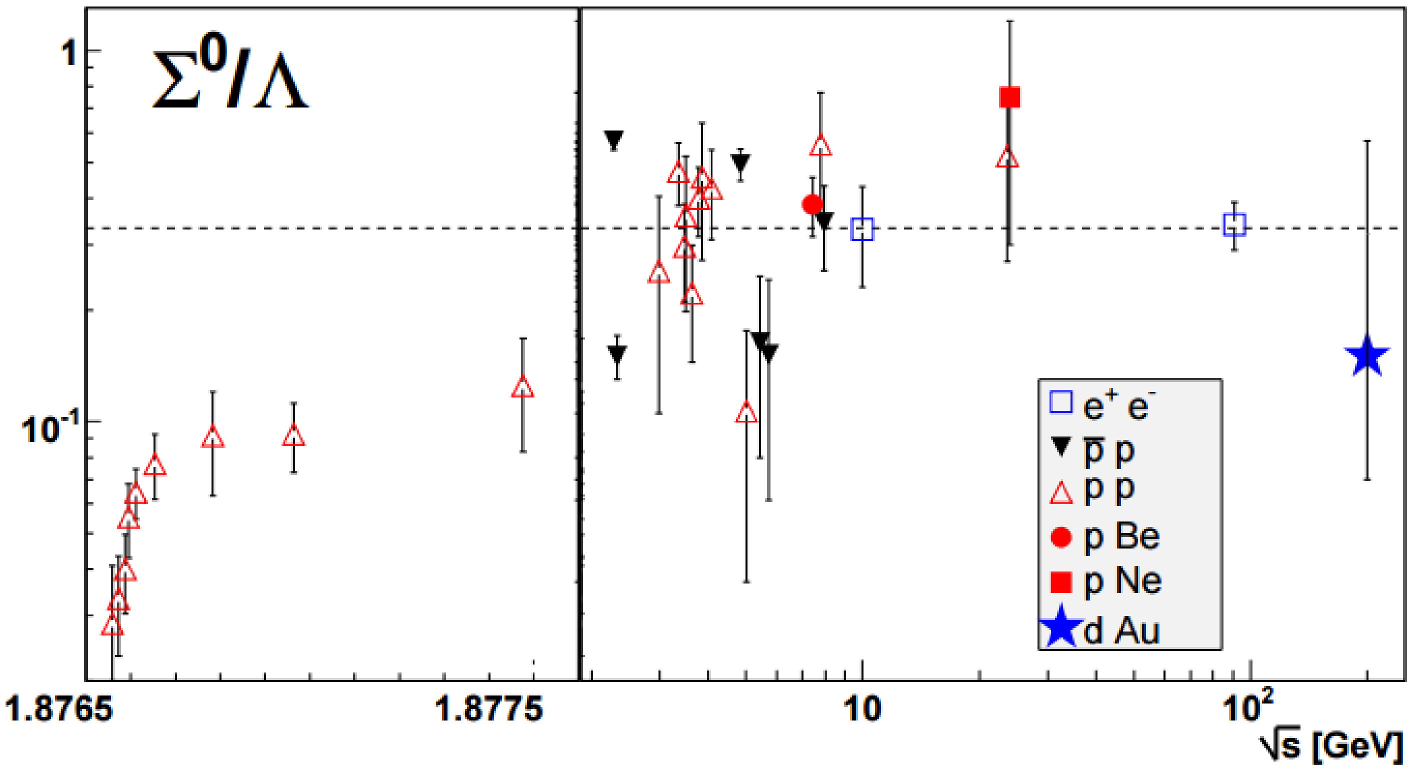


Figure 4: Σ^0/Λ results versus collision $\sqrt{s}$ ($\sqrt{s_{NN}}$ for p/d+A) [1]. Meson-nucleon reaction results are excluded for clarity, but exist only at intermediate energies and lie in the same range. The dashed line is the ratio of isospin degeneracy factors (1/3).

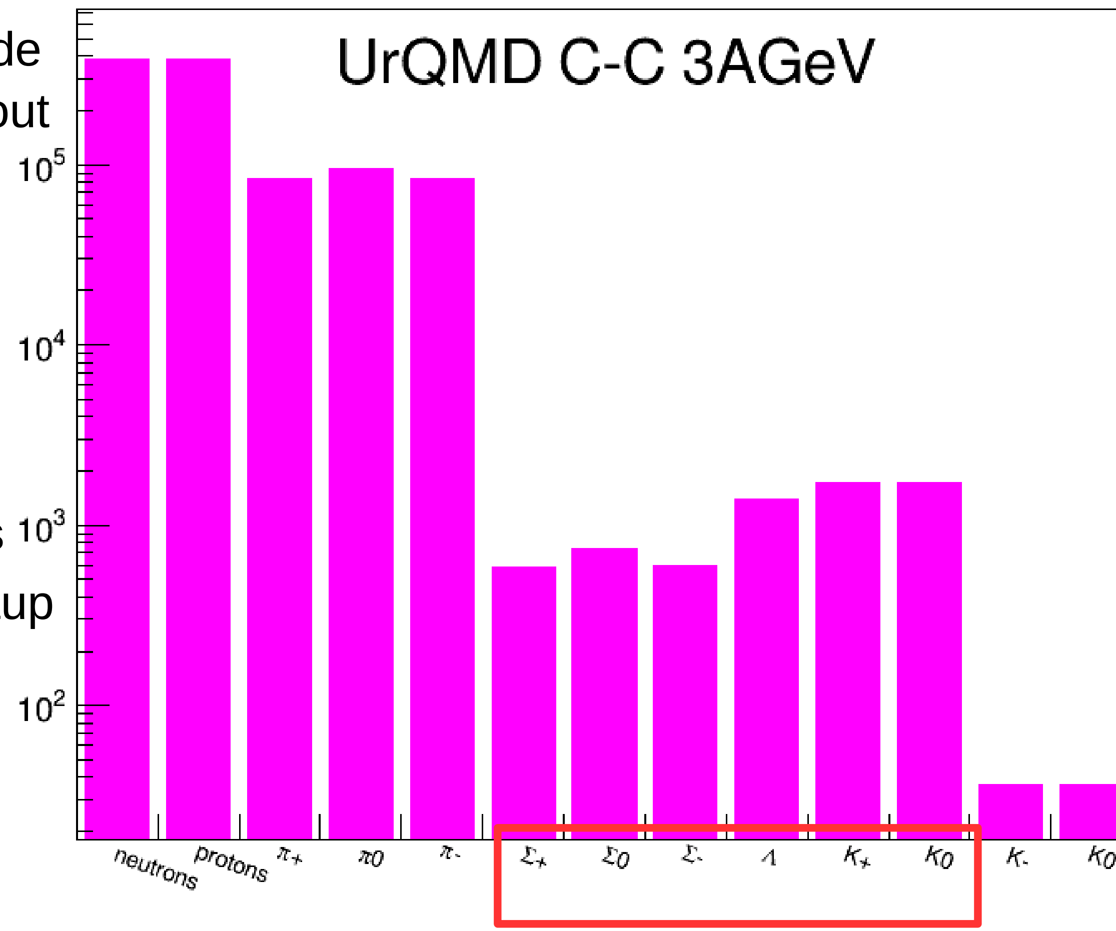
arXiv:nucl-ex/0512018,G.Van Buren for the STAR collaboration

UrQMD model

- **U**ltra **R**elativistic **Q**uantum **M**olecular **D**ynamics model* is Monte-Carlo simulation package for p-p, p-A and A-A interactions

- UrQMD model describes good many processes of nuclear interactions in wide energy range, contains information about a lot of known particles and free to use (https://urqmd.org)

- UrQMD vers.3.4 without any special add-ons was used for simulating most centrality interactions for C-C collisions at energies close to BM@N (NICA) setup



UrQMD simulations for C-C

- Particle production for different energies (10^5 events)

$K^+ = u\underline{s}$, $K^0 = d\underline{s}$, $\underline{K}^0 = \underline{d}s$, $K^- = \underline{u}s$, $K_S=(d\underline{s}+s\underline{d})/\mathrm{sqrt}2$, $K_L=(d\underline{s}-s\underline{d})/\mathrm{sqrt}2$

CC,UrQMD,10^5 ev.	2AGeV	3AGeV	4AGeV	10AGeV	30AGeV
All particles	2968383	3269875	3555732	4785049	6861519
P	980372	973357	964317	934470	899765
N	982267	974936	965797	937139	900696
Λ	1393	5493	10405	30537	57559
Σ^+	489	2347	4389	11135	17909
Σ^0	623	2918	5653	12424	19557
Σ^-	549	2277	4321	11209	18108
π^+	178772	269480	354107	714208	1286150
π^0	205822	312142	407661	796030	1418912
π^-	178205	267809	354088	713459	1286178
K^+	1607	6884	13574	45080	108427
K^0	1506	6741	13218	44376	108090
antiK^0	30	279	942	11760	51677
K^-	27	279	918	11516	51639

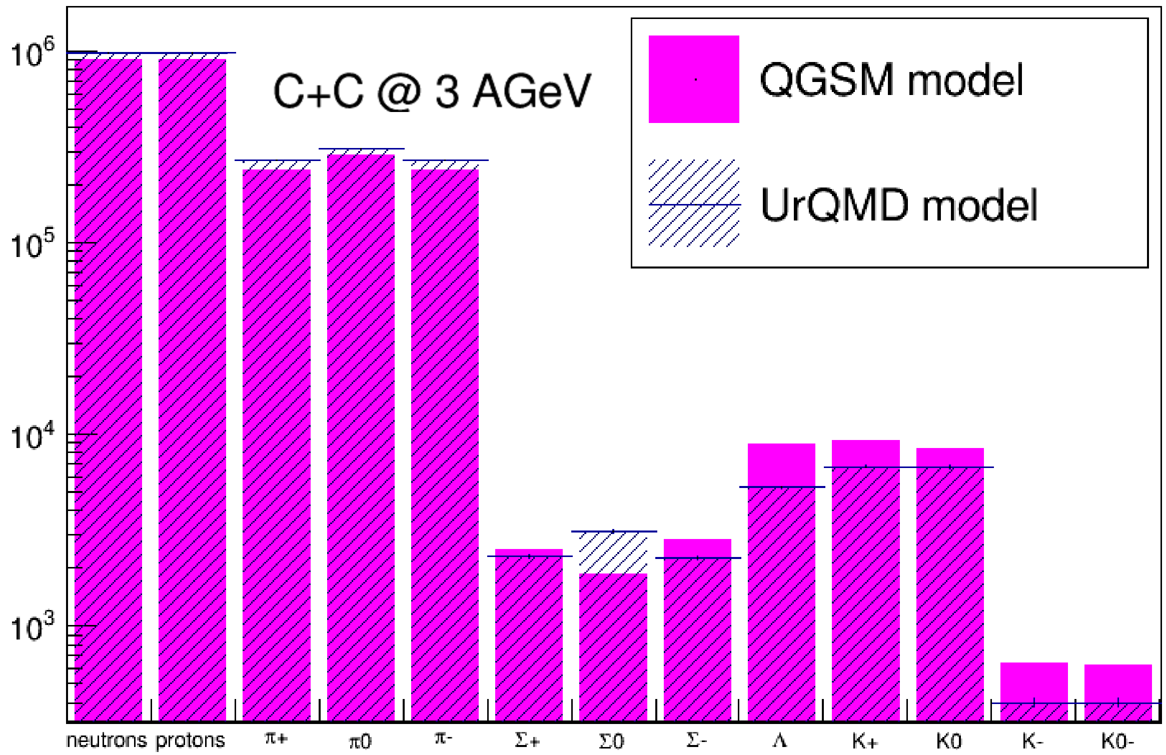
UrQMD predictions for Σ^0/Λ

- Σ^0/Λ can give estimate about % direct Λ and Λ borning from Σ^0
- Σ^0/Λ isn't constant, it depends from energy
- That value changes from 0.31 up to 0.54 in UrQMD model

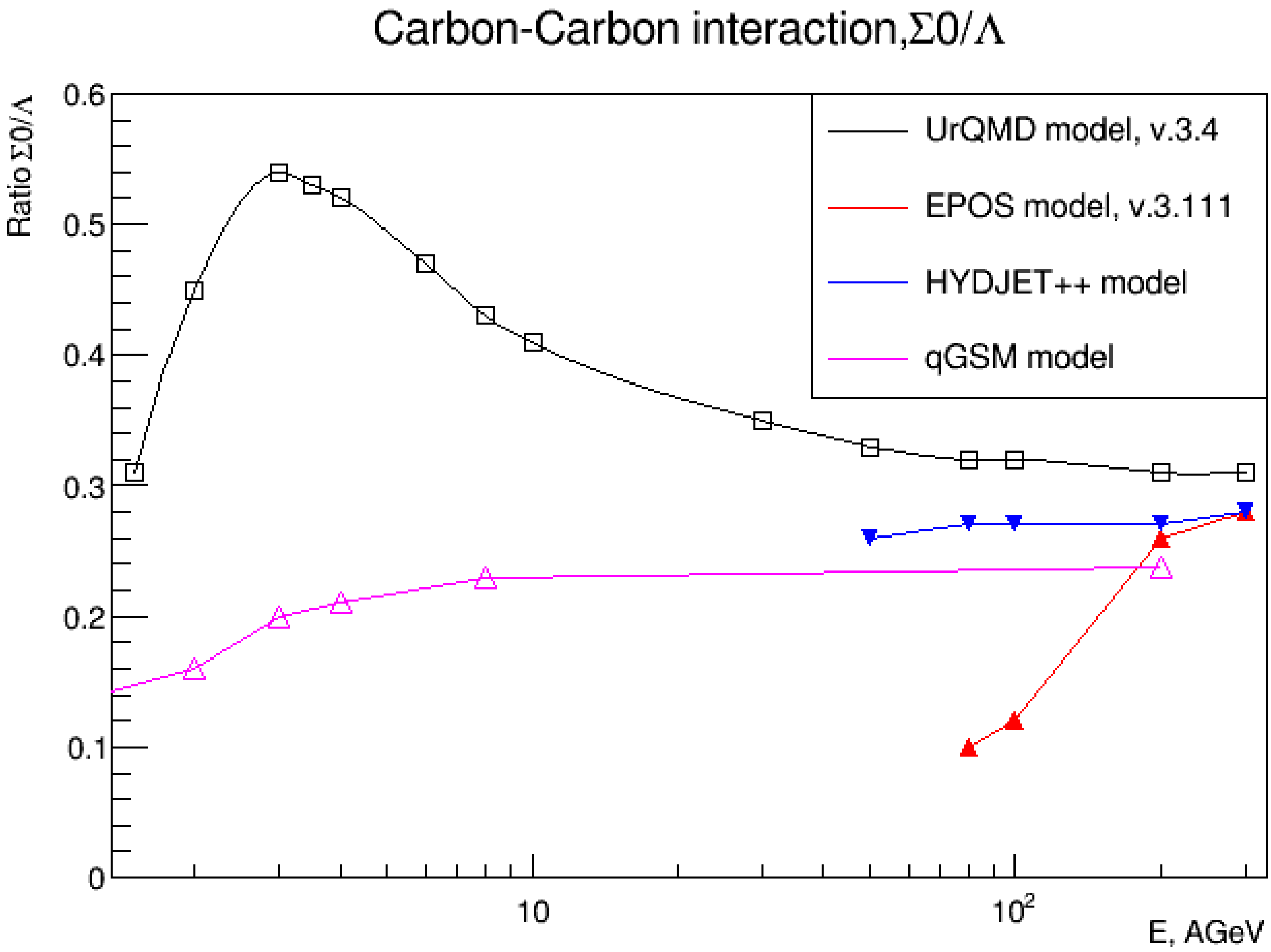
C+C, E_0, AGeV	1.5	2	3	3.5	4	6	8	10	30	100
Σ^0/Λ	0.31	0.48	0.53	0.52	0.54	0.47	0.43	0.41	0.34	0.32

Other models

- EPOS (Energy conserving quantum mechanical approach, based on Partons, p.ladders, strings, Off-shell remnants and splitting of p.ladders, v. 3.111, K.Werner)
- HYDJET++ (For rel. HI AA-coll. as a superposition of soft, hydro and hard state from multi-parton fragmentation,v. 2.3, http://lokhtin.web.cern.ch/lokhtin/hydjet++/)
- QGSM (Quark Gluon String Model,http://mpd.jinr.ru/computing/db/simulation/)

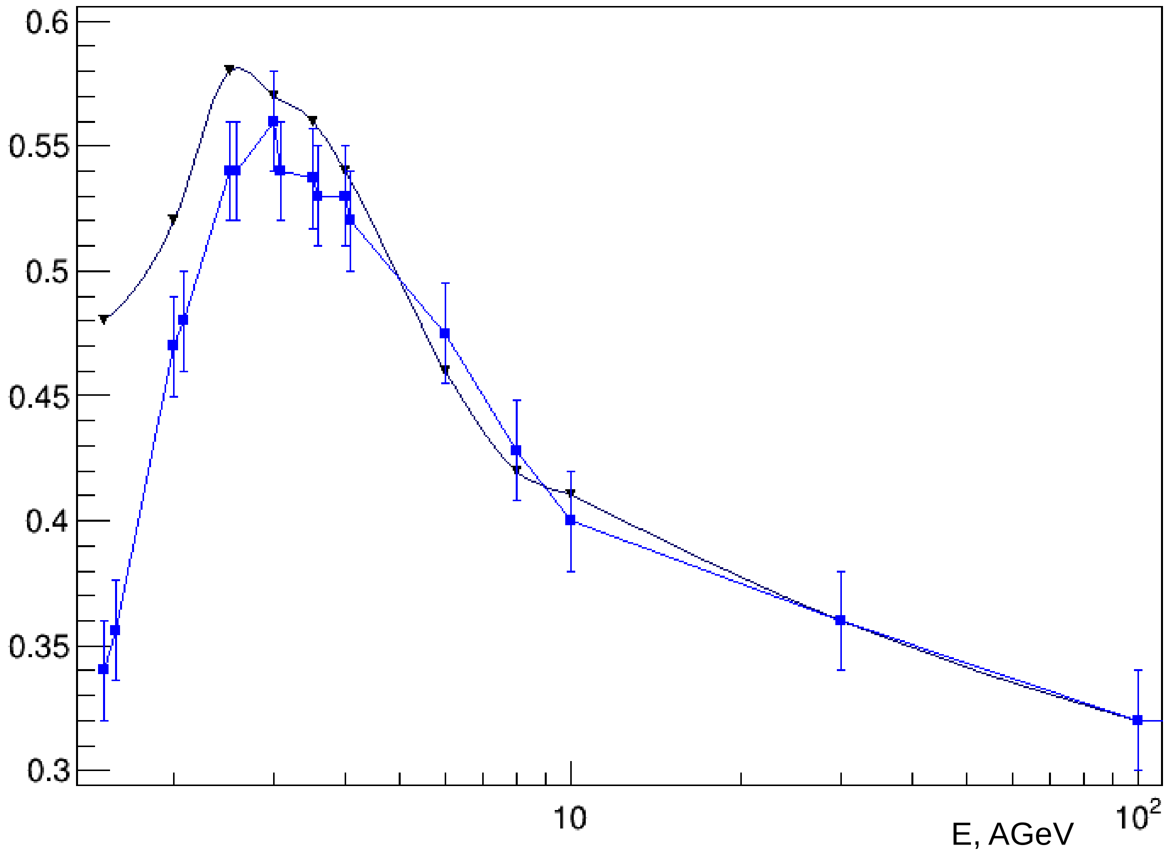


Models predictions for Σ^0/Λ



UrQMD predictions for Σ^0/Λ

Σ^0/Λ with correction on threshold (77 MeV) and without correction (blue line)



Hyperon reconstruction

Σ^+ -> $p\pi^0$ (52 %) , $n\pi^+$ (48 %)

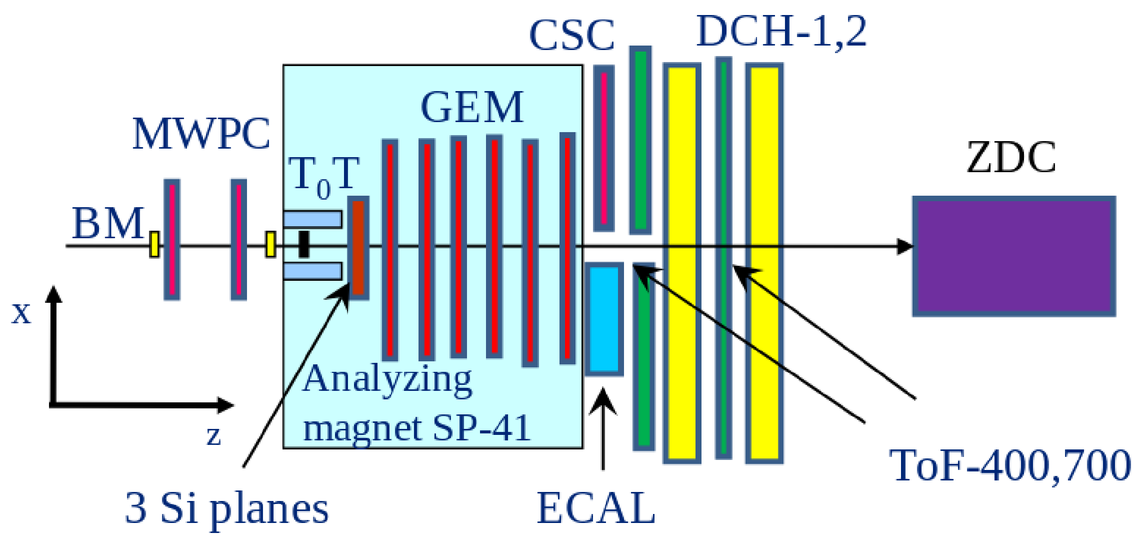
Σ^- -> $n\pi^-$ (100 %)

Σ^0 -> $\gamma\Lambda$ (100 %) -> $\gamma\pi^- p$ (~64%)

- It is necessary to identificate neutrons and gammas
- This information for neutrons and gammas → from electromagnetic calorimeter → ECal (BM@N):

->“shashlyk” type,
consist of different layers
of Pb and Sc

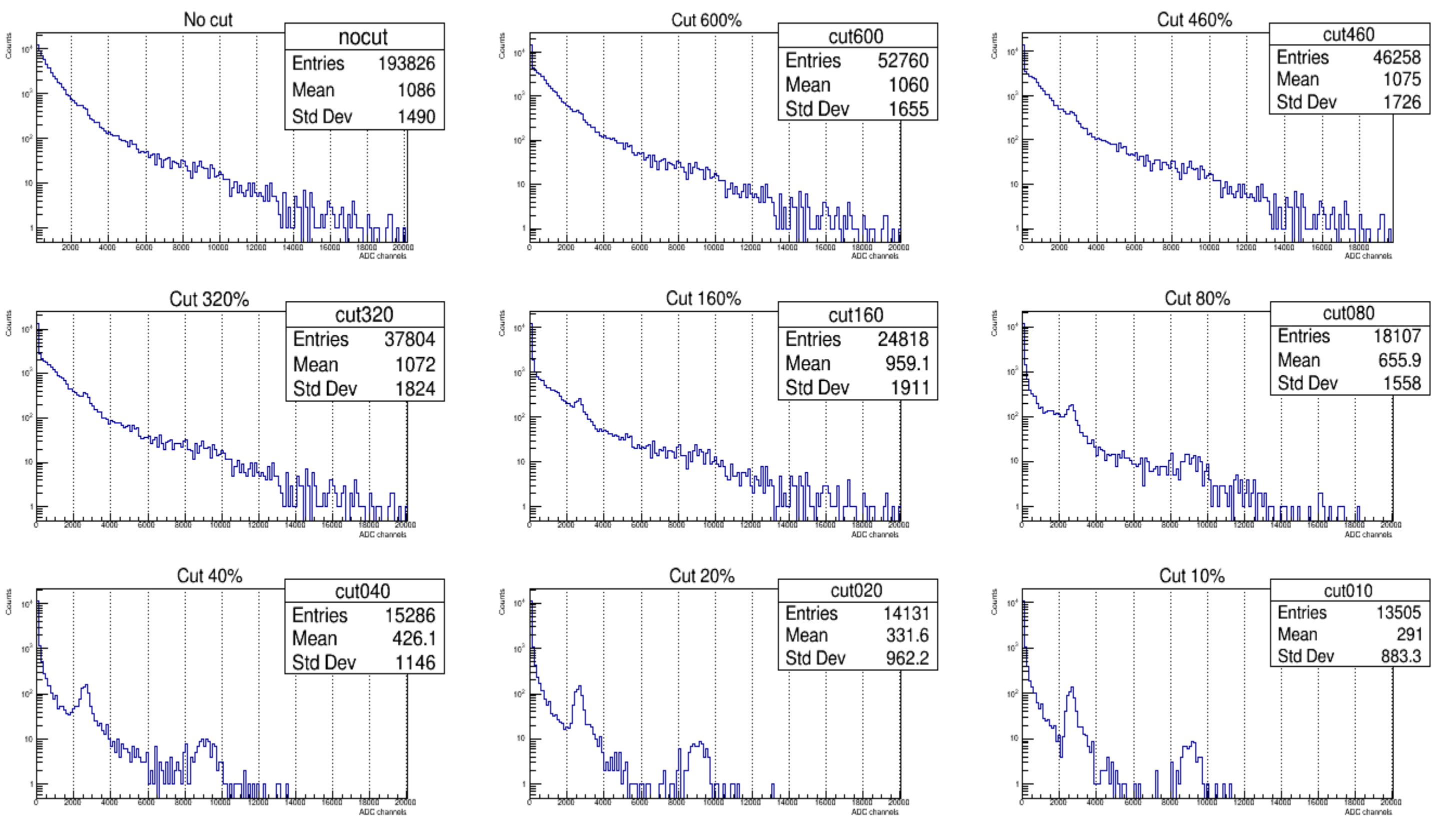
->full setup is 504 channels



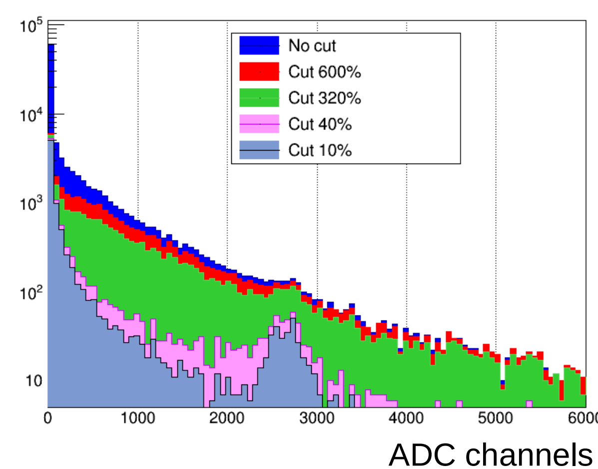
(from BM@N collab.reports)

Ecal beam calibration (BM@N)

- Seans 55(March,2018),C-Pb run, T_0=3.2 GeV/n
- Different cuts on energy sum of 8 channels around the main for each Ecal channel and then calibrating all Ecal channels on MIP position
- These calibrations can be used for energy-ADC transition

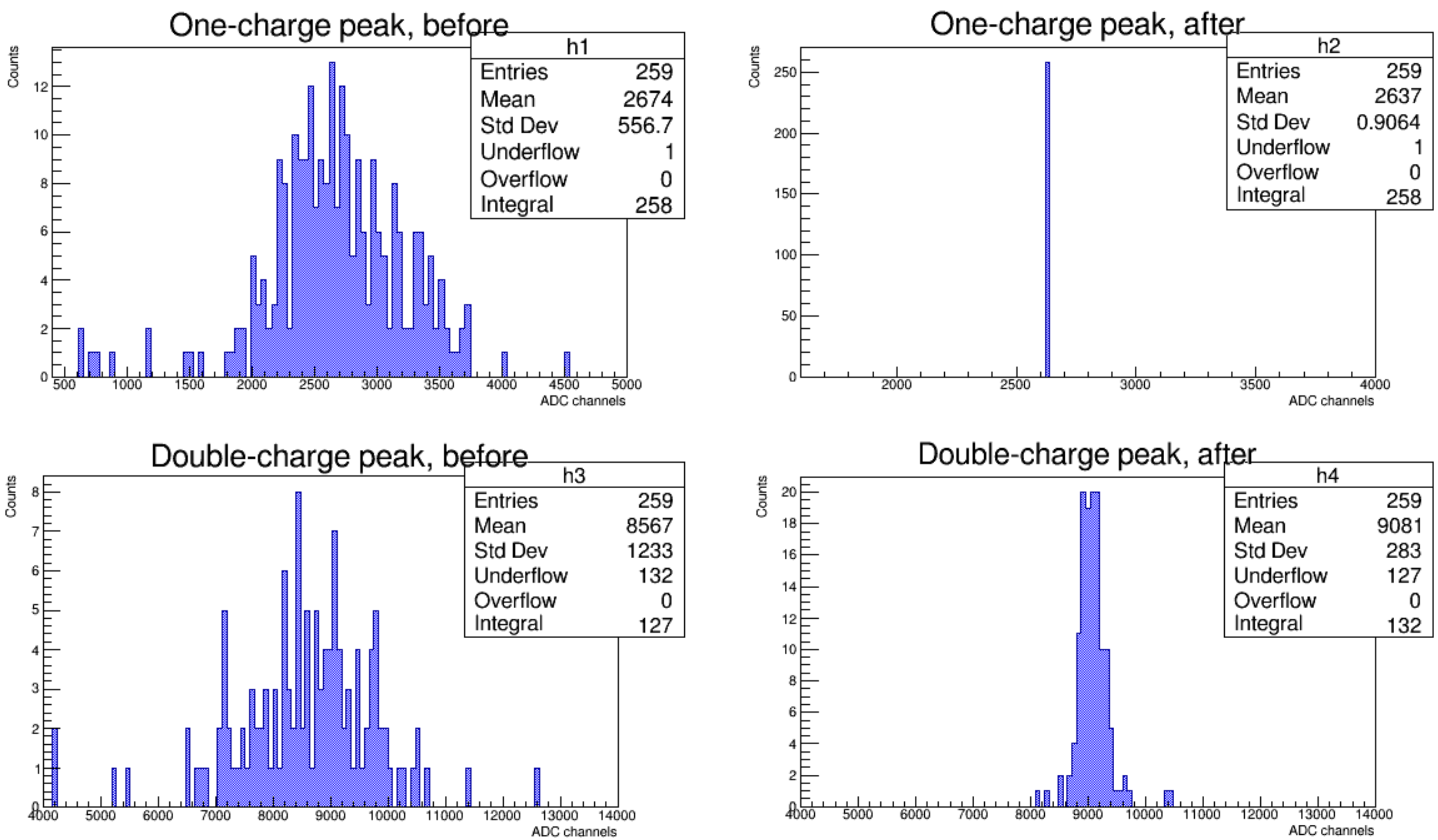


371	392	413	434	455
370	391	412	433	454
369	390	411	432	453
368	389	410	431	452
367	388	409	430	451



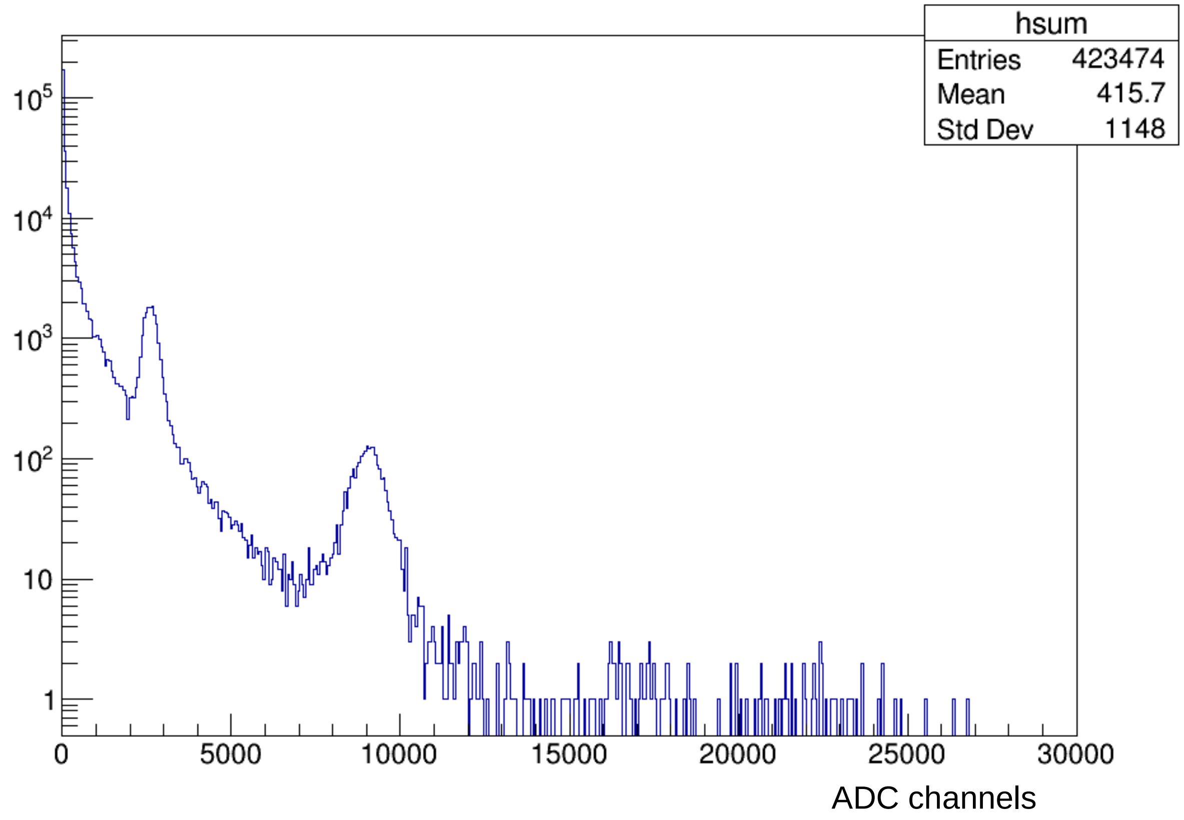
Ecal beam calibration (BM@N)

- Calibrations on MIP position for one-charge and double-charge peak in Ecal channels
-



Ecal beam calibration (BM@N)

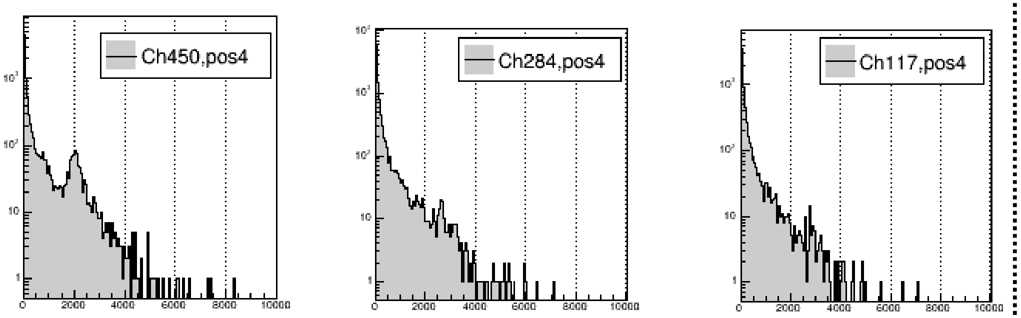
- Sum of calibrated Ecal channels
- Peaks from one-charge and double-charge particles are visible



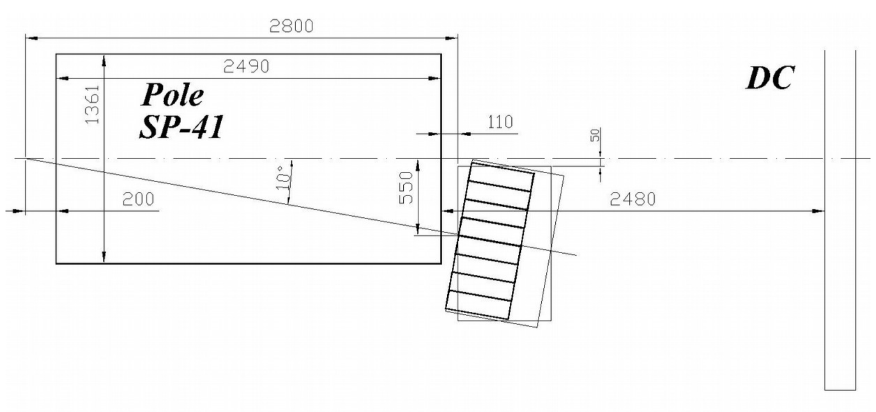
Ecal krypton data (BM@N)

- Kr-Cu run, T_0=2.6 GeV/n
- Two ecal position, 4th-closer to beam, 5th- far from the beam

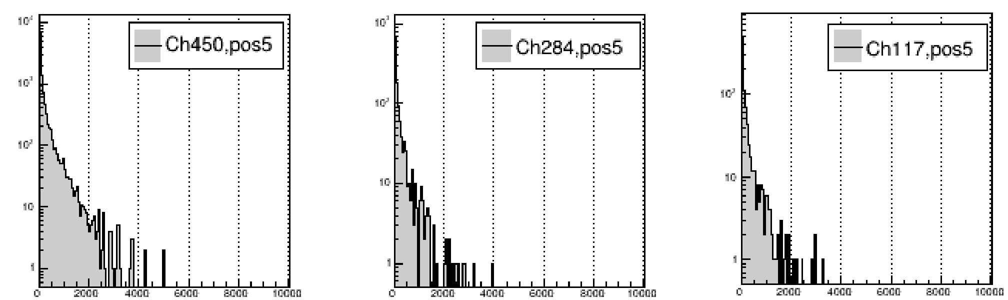
<u>Position 4</u>



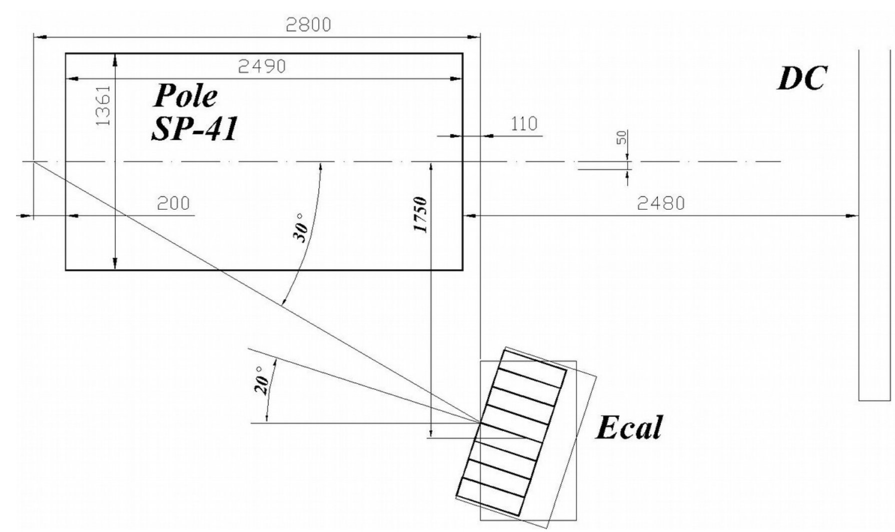
α~2° α~10° α~16°



<u>Position 5</u>

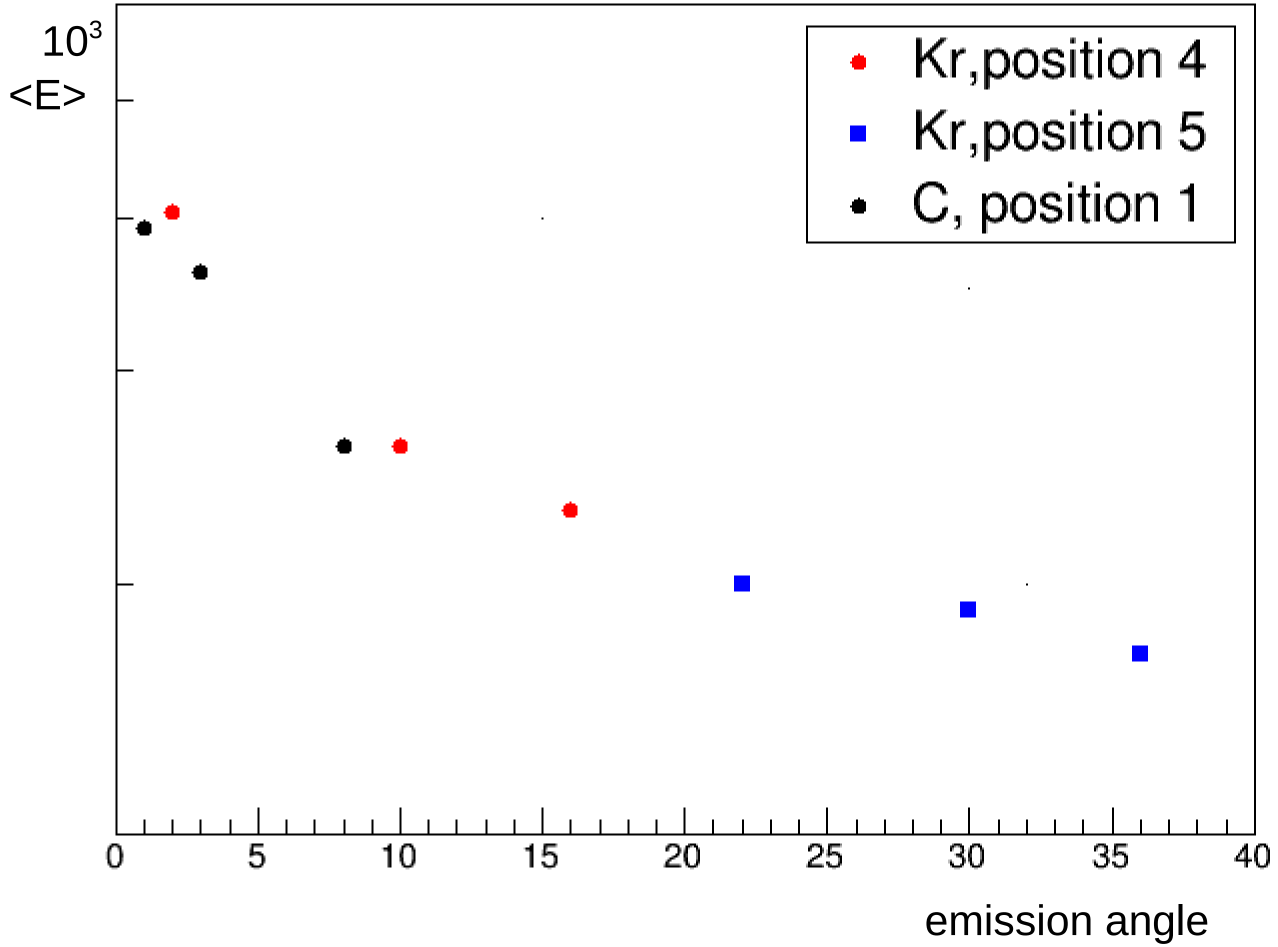


α~22° α~30 α~36°



<E> vs emission angle

- Energy-angle dependence for Ecal channels (>80% of energy in main channel cut) for different data



Conclusions

- Sigma-hyperons - essential part of strange particle production
- Models describes amount of hyperons at energies at few GeV/c, but these estimates are model- and energy-depended
- Not enough experiment data for sigma-hyperons– still no data for A-A collision
- To do: π^0 -reconstruction via Ecal(BM@N)

Backup

Backup

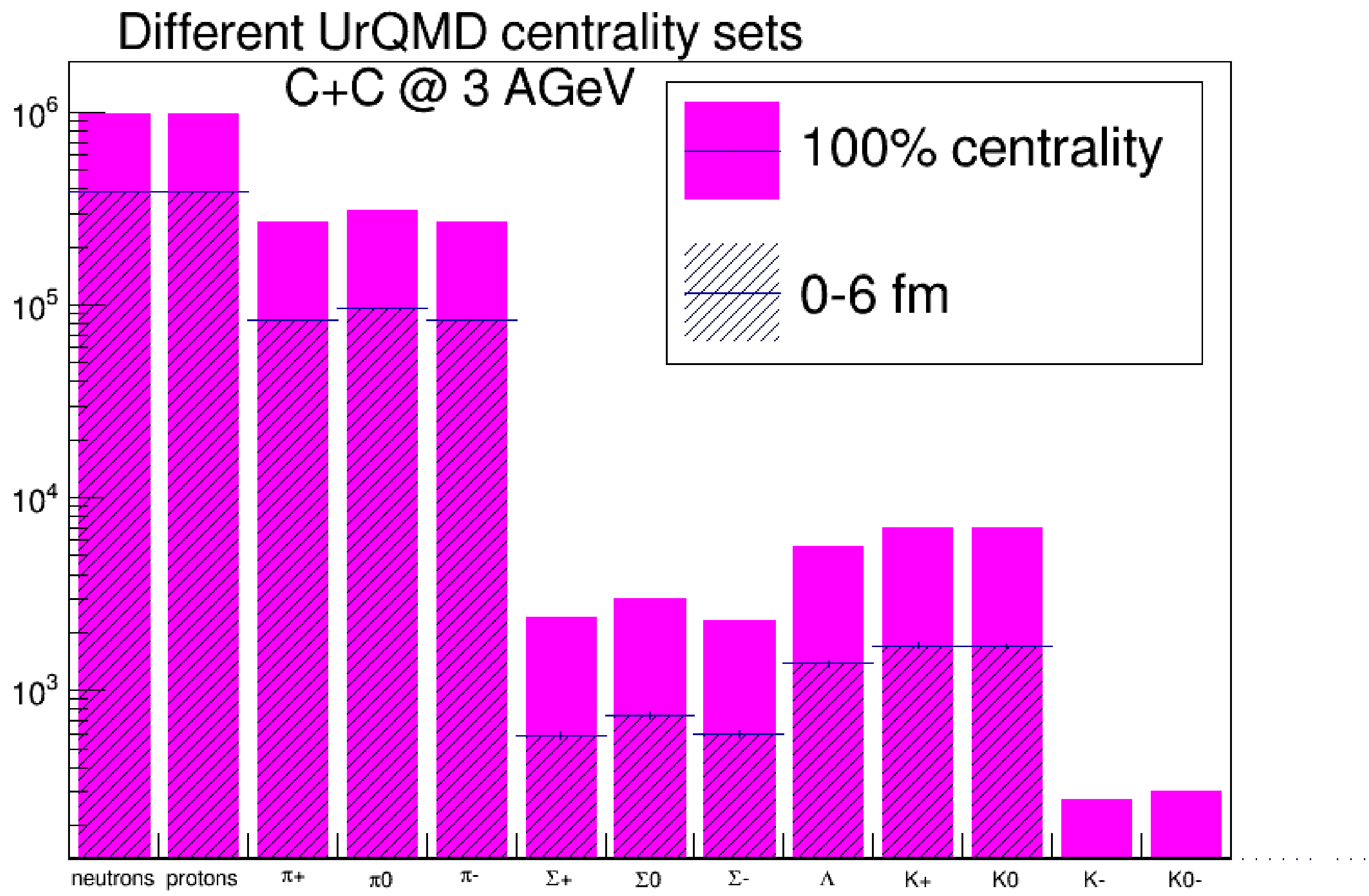
UrQMD: ~ 1AGeV ++; A+p,A+A

HYDJET++: sqrt(s)~10 GeV; A+A

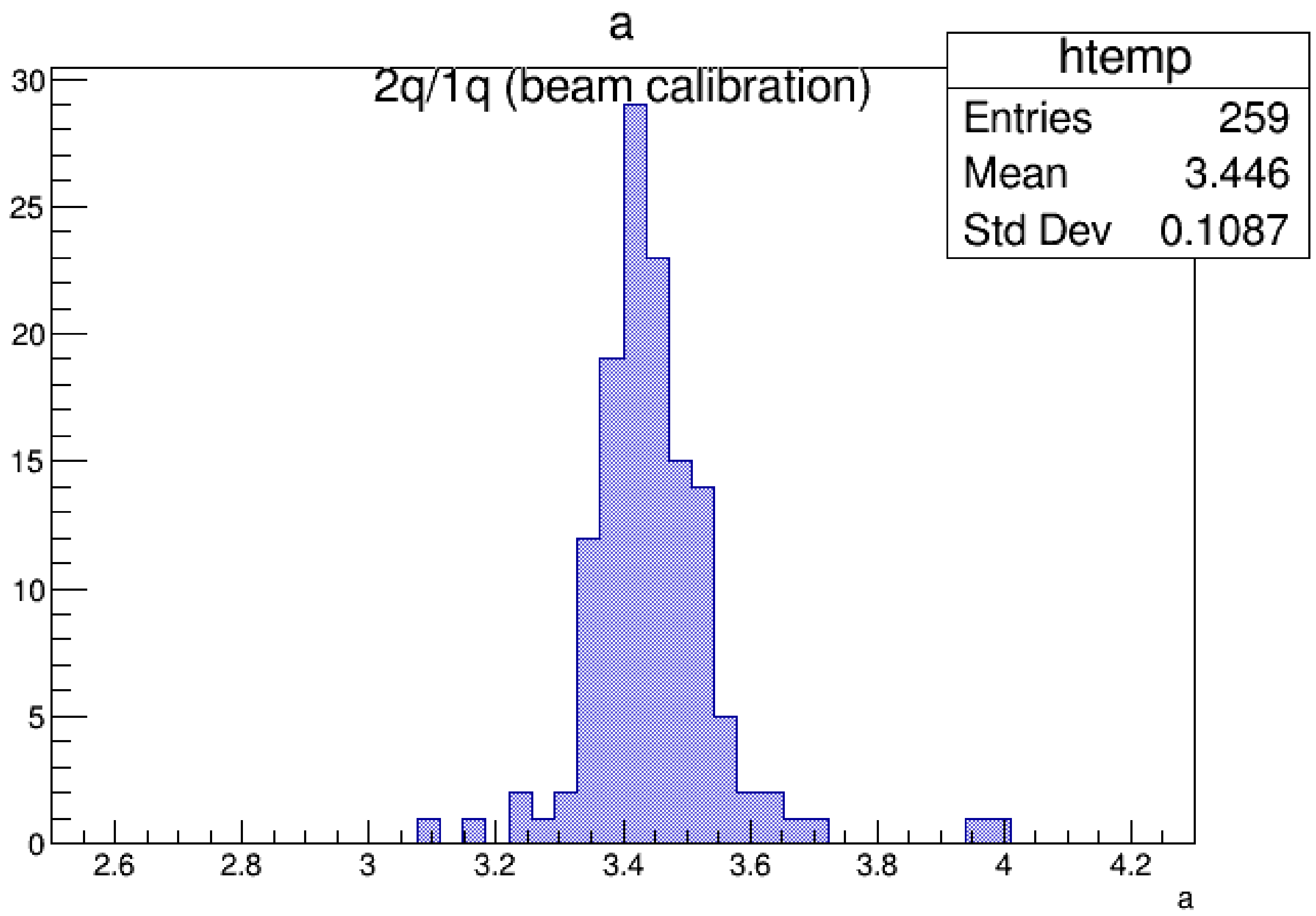
EPOS: 5+5 GeV for pp, A+p,A+A

QGSM: 50 GeV for pp;

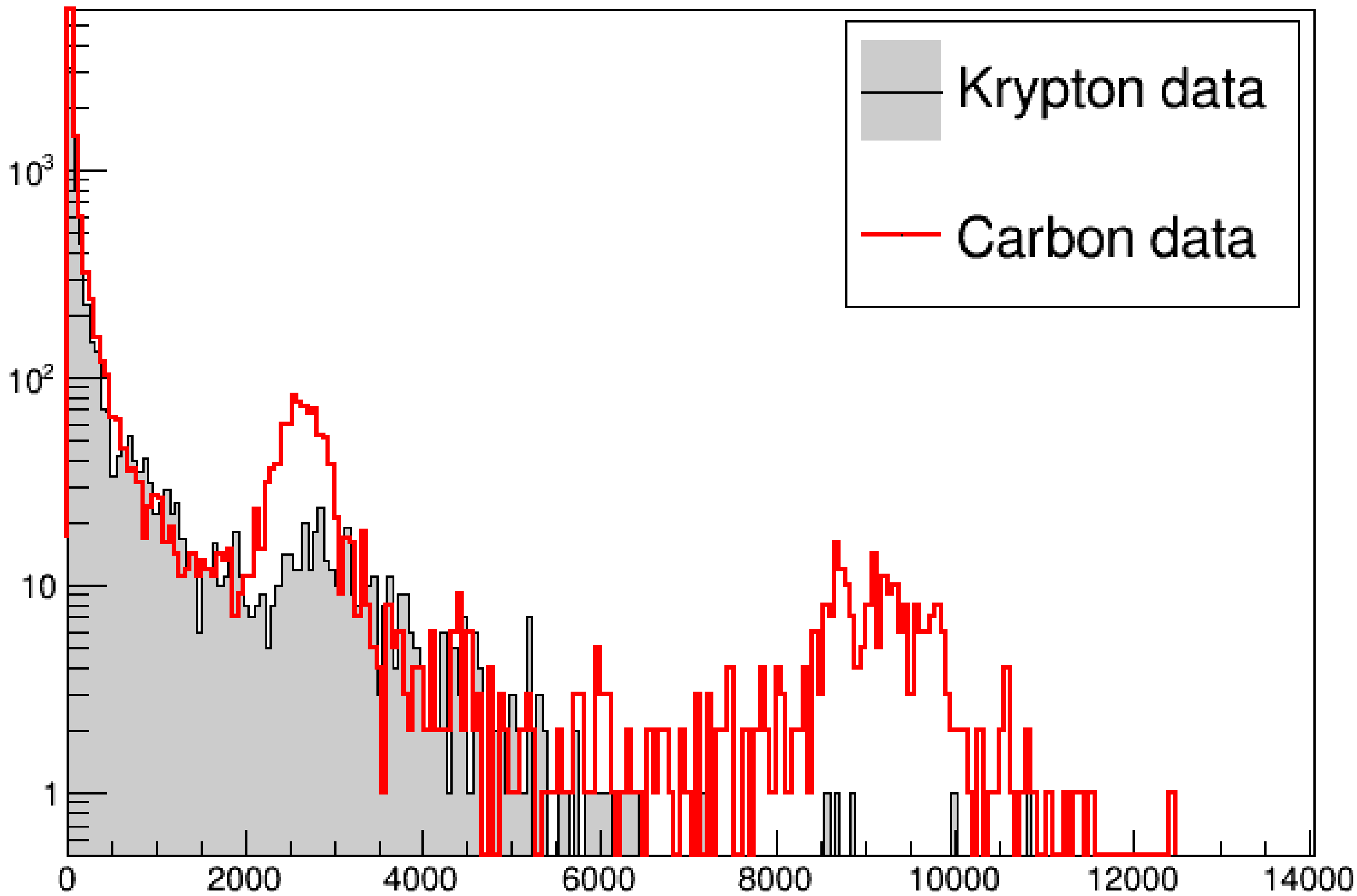
Backup


Different UrQMD centrality sets
C+C @ 3 AGeV
100% centrality
0-6 fm
10^6
10^5
10^4
10^3
neutrons
protons
π+
π0
π-
Σ+
Σ0
Σ-
Λ
K+
K0
K-
K0-

Backup


a
2q/1q (beam calibration)
htemp
Entries 259
Mean 3.446
Std Dev 0.1087
30
25
20
15
10
5
0
2.6
2.8
3
3.2
3.4
3.6
3.8
4
4.2
a

Backup



Krypton data
Carbon data
10^3
10^2
10
1
0
2000
4000
6000
8000
10000
12000
14000