Faculty of Physics
WARSAW UNIVERSITY OF TECHNOLOGY

Perspectives for baryon-baryon Femtoscopy at MPD

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Warsaw University of Technology

Outline

Introduction

Femtoscopy

Femtoscopy of protons

Femtoscopy of exotic hadrons

Model predictions

Pans for the future

WUT Group

Professors: A. Kisiel, J. Pluta

PhDs: D. Wielanek

PhD students: M. Milewicz-Zalewska <- PhD thesis related to B-B correlations @ MPD

Femtoscopy

Technique used to extract information about spatio-temporal structure of event

Base on two particle correlations

Correlation function defined as

$$q = \sqrt{(p_1 - p_2)^2 - (E_1 - E_2)^2}$$

$$C(q) = \frac{P(p_1, p_2)}{P(p_1)P(p_2)}$$

Theoretical shape of the CF

Let's consider noninteracting bosons with spin zero, single particle probability of emission

$$\rho(x) \approx e^{-\left(\frac{x^2}{2R^2}\right)}$$

Probability of pair emission is:

$$\rho(\Delta x) \approx e^{-\left(\frac{\Delta x^2}{4R^2}\right)}$$ ~1/R

Influence of quantum statistic term:

$$|\Psi(\Delta x, \Delta p = q)|^2 = 1 + \cos(\Delta x q)$$

Correlation function

$$C(q) = \int \rho(x_1, p_1)\rho(x_2, p_2)|\Psi(x_1, p_1, x_2, p_2)\Big|^2 dx_1 dx_2 = 1 + e^{-q^2R^2}$$

Theoretical shape of the CF

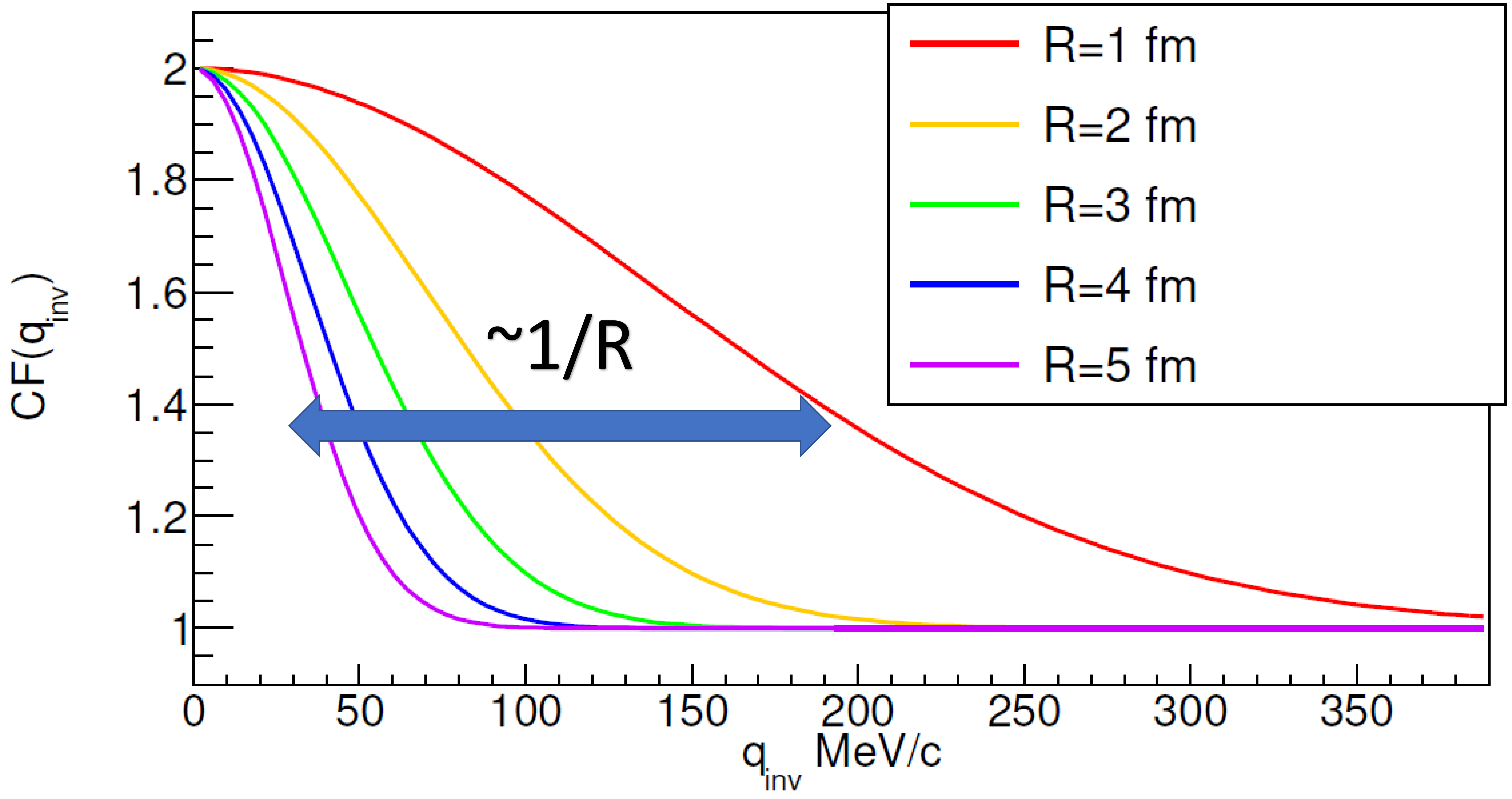
Let's consider noninteracting bos

Probability of pair emission is:

Influence of quantum statistic ter

Correlation function

$C(q) = \int \rho(x$



Applications of femtoscopy

Known interactions ($|\Psi(x_1, p_1, x_2, p_2)|^2$)e.g. proton-proton:

$$C(q) = \int \rho(x_1, p_1)\rho(x_2, p_2)|\Psi(x_1, p_1, x_2, p_2)\Big|^2 dx_1 dx_2 \rightarrow \rho(x_1, p_1)\rho(x_2, p_2)$$

Unknown interactions, known/assumed size of the source ($\rho(x_1, p_1)\rho(x_2, p_2)|$) e.g. lambda-lambda:

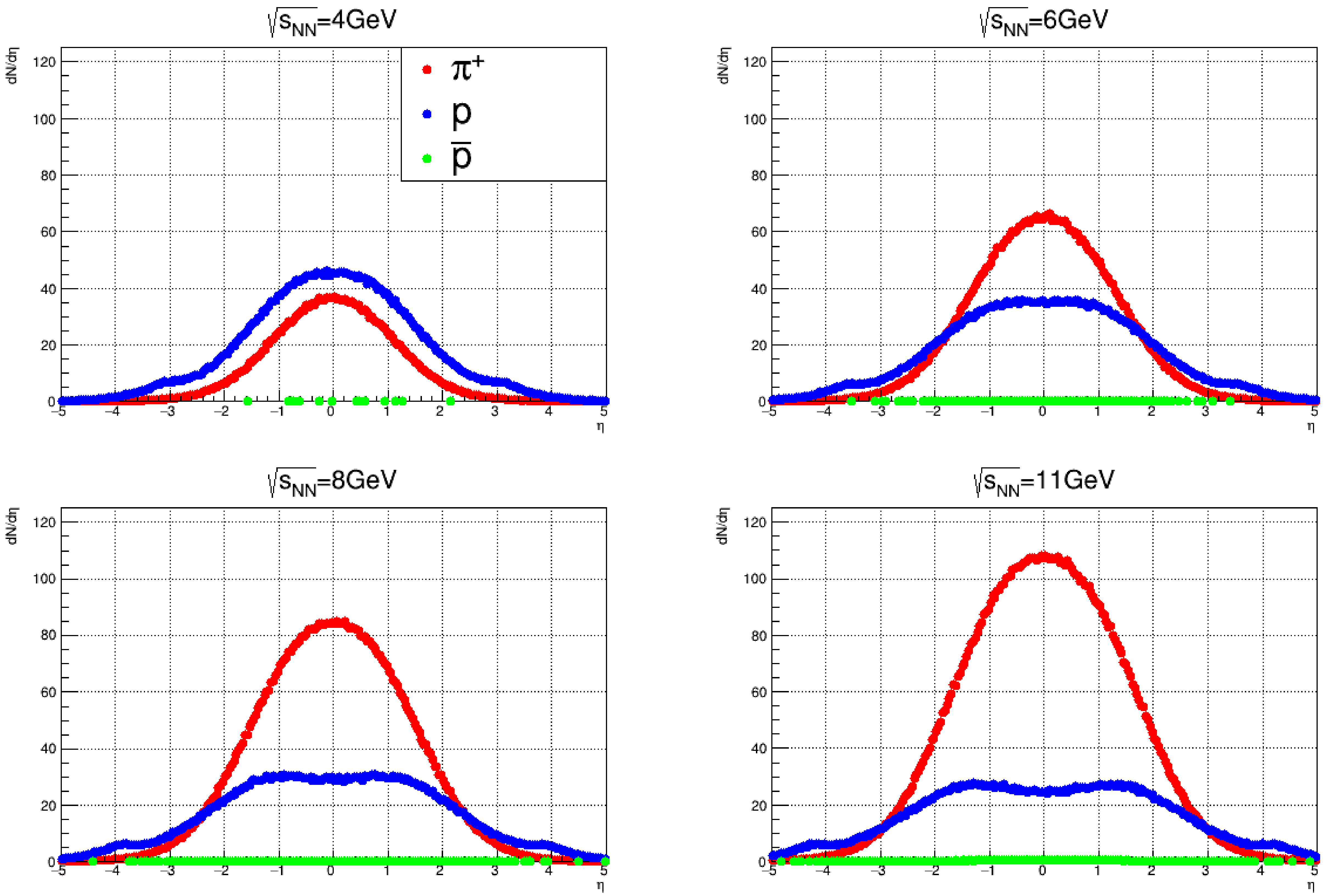
$$C(q) = \int \rho(x_1, p_1)\rho(x_2, p_2)|\Psi(x_1, p_1, x_2, p_2)\Big|^2 dx_1 dx_2 \rightarrow |\Psi(x_1, p_1, x_2, p_2)\Big|^2$$

Plan of work

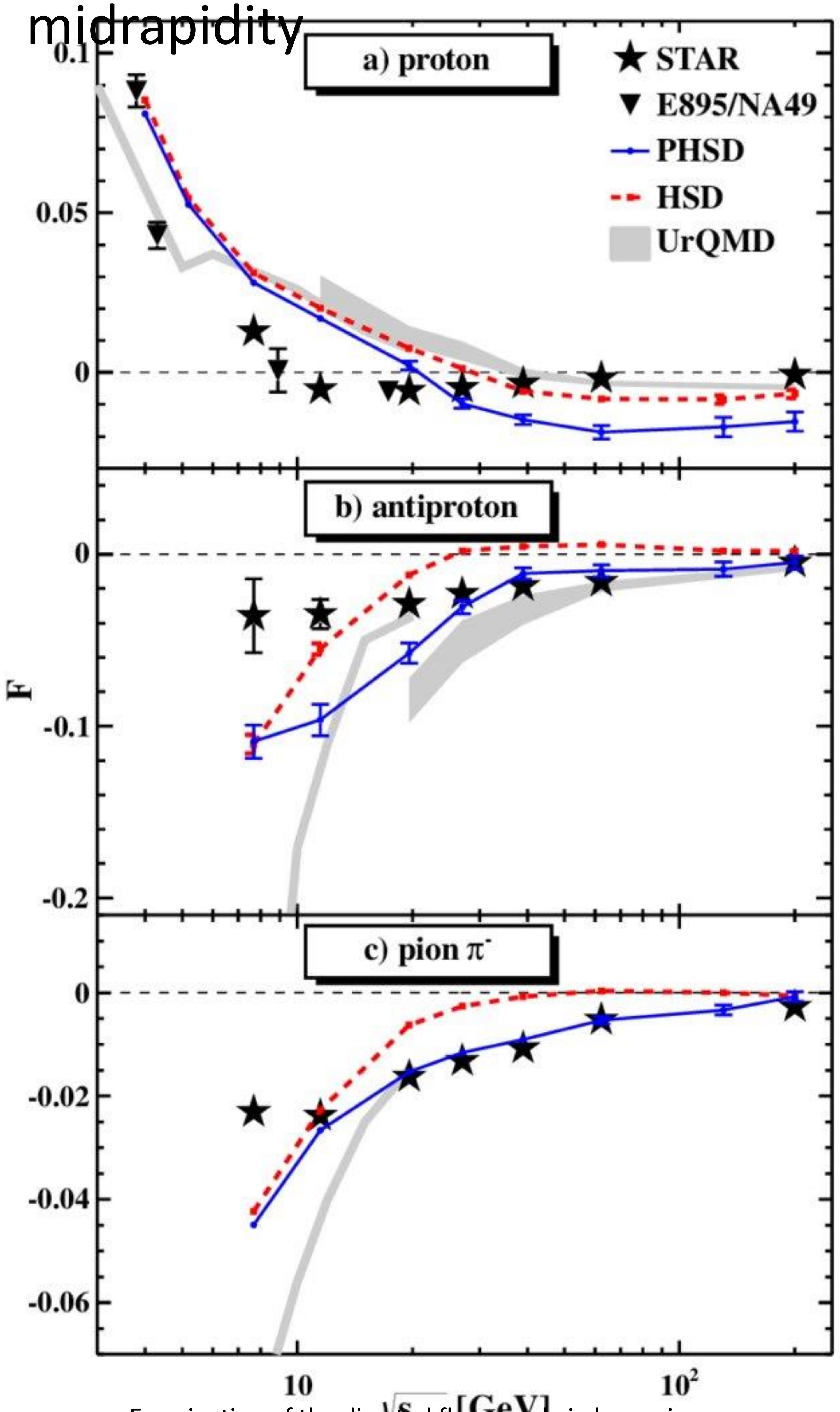
Step one: look at the models!

Femtoscopy of protons

UrQMD 3.4 AuAu central 0-5%



Directed flow slope at midrapidity



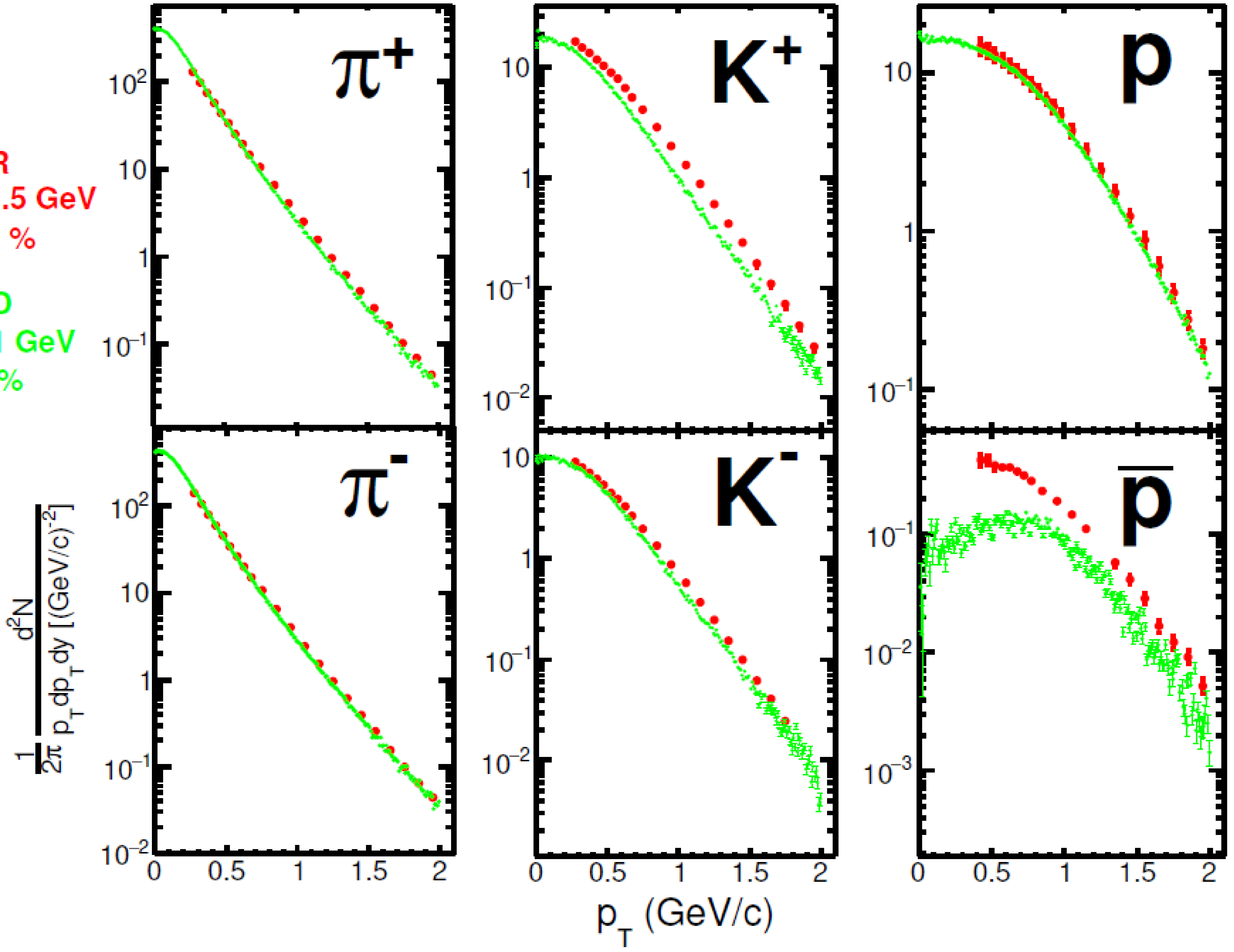
Examination of the directed flow puzzle in heavy-ion collisions, V. P. Konchakovski et al.

Warsaw University of Technology

Femtoscopy of protons

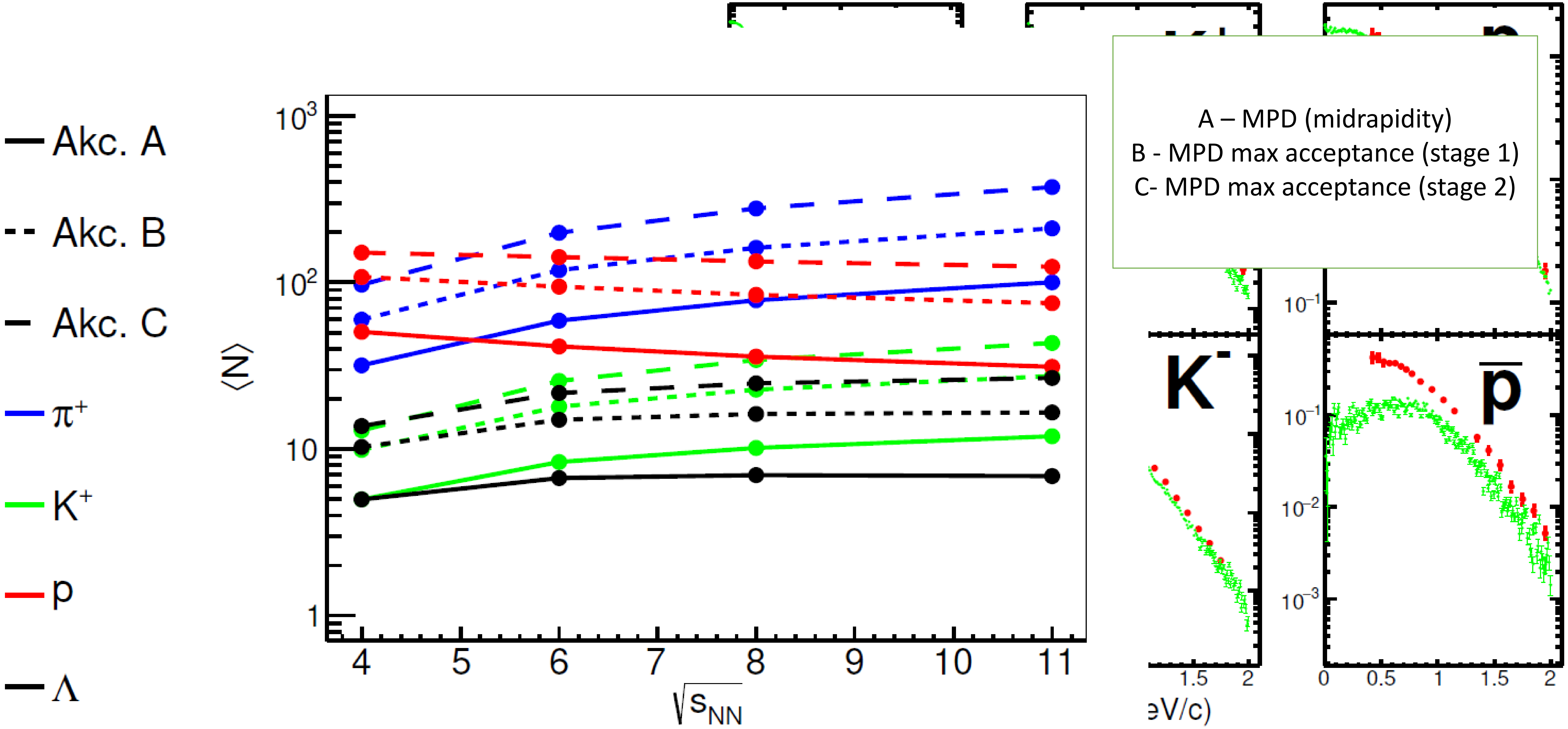
STAR
AuAu @ 11.5 GeV
C = 0-5 %

UrQMD
AuAu @ 11 GeV
C = 0-5%



D. Wielanek PhD thesis

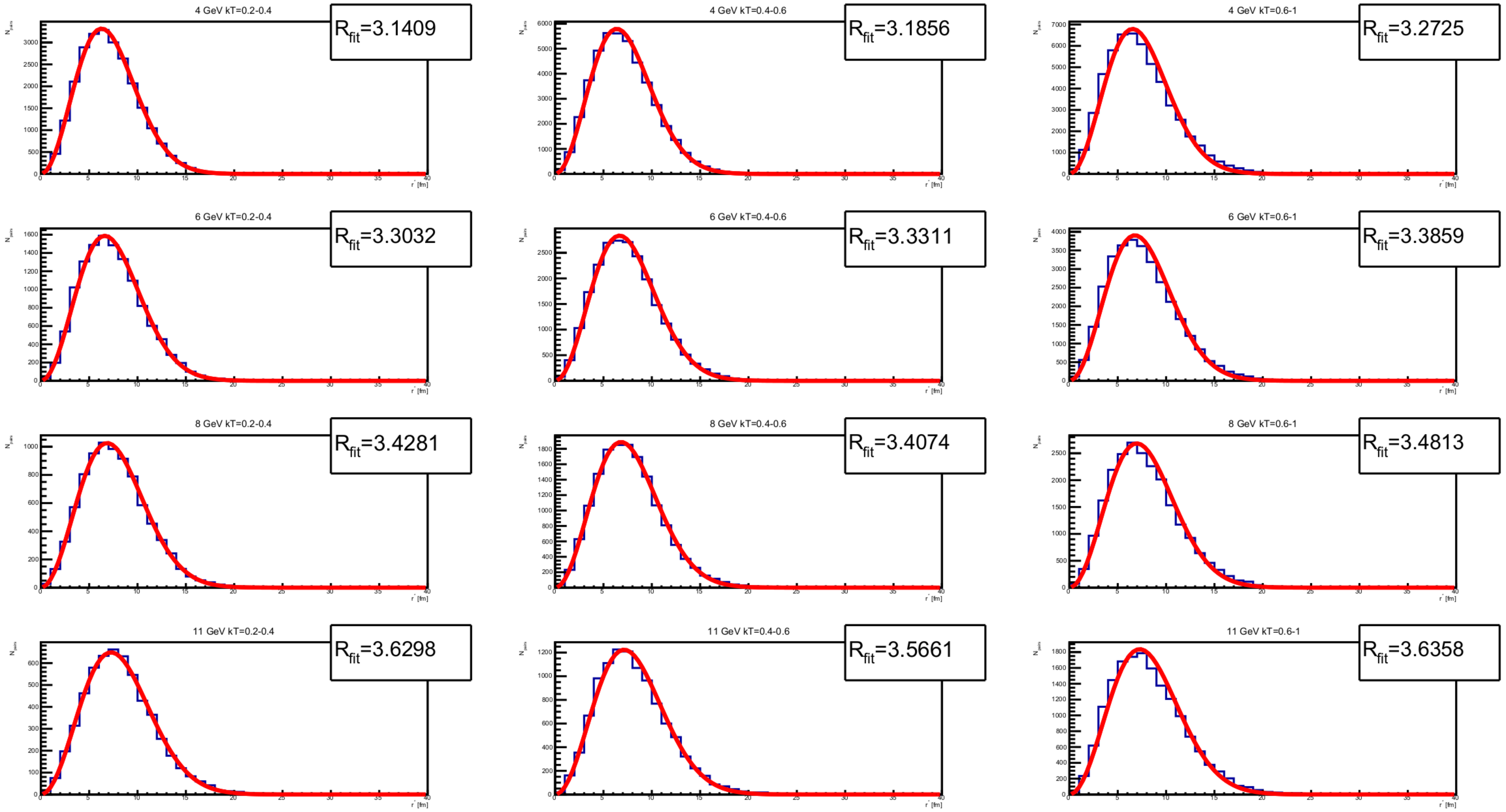
Femtoscopy of protons



A – MPD (midrapidity)
B - MPD max acceptance (stage 1)
C- MPD max acceptance (stage 2)

Femtoscopy of protons

Proton-proton estimation of source emission function (central collision, midrapidity, gives radius at range 3-3.5 fm.
Source is well approximated by gaussian shape.



Femtoscopy of protons

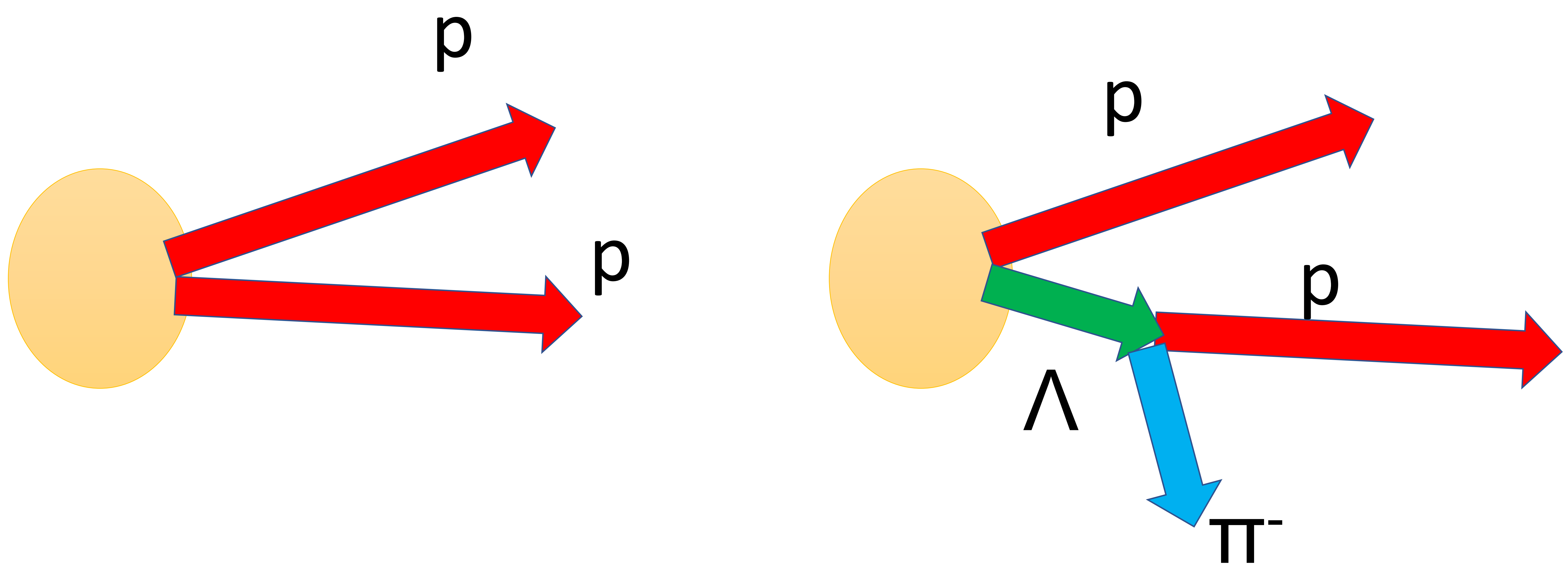
Problem of residual correlations:

We cannot fit p-p function like this:

$$C(q) = N\left(1 + \lambda C_{pp}(q)\right)$$

We should do this like this:

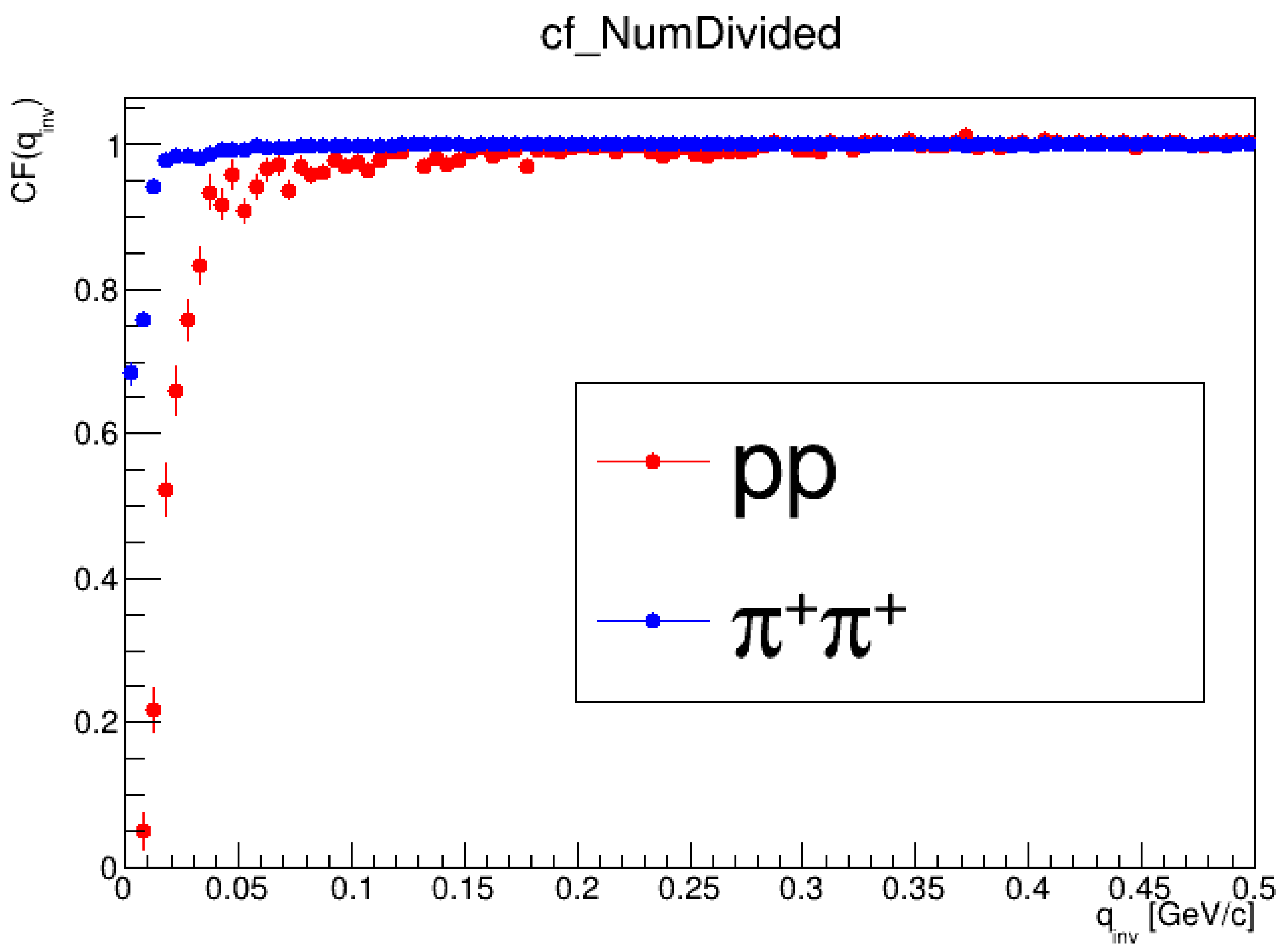
$$C(q) = N(1 + \lambda_{pp}C_{pp}(q) + \lambda_{p\Lambda}C_{p\Lambda}(\tilde{q}) + \lambda_{\Lambda\Lambda}C_{\Lambda\Lambda}(\tilde{q}) + \cdots)$$



Femtoscopy of protons

Results of analysis with UrQMD 7 GeV beam – no two particle cuts

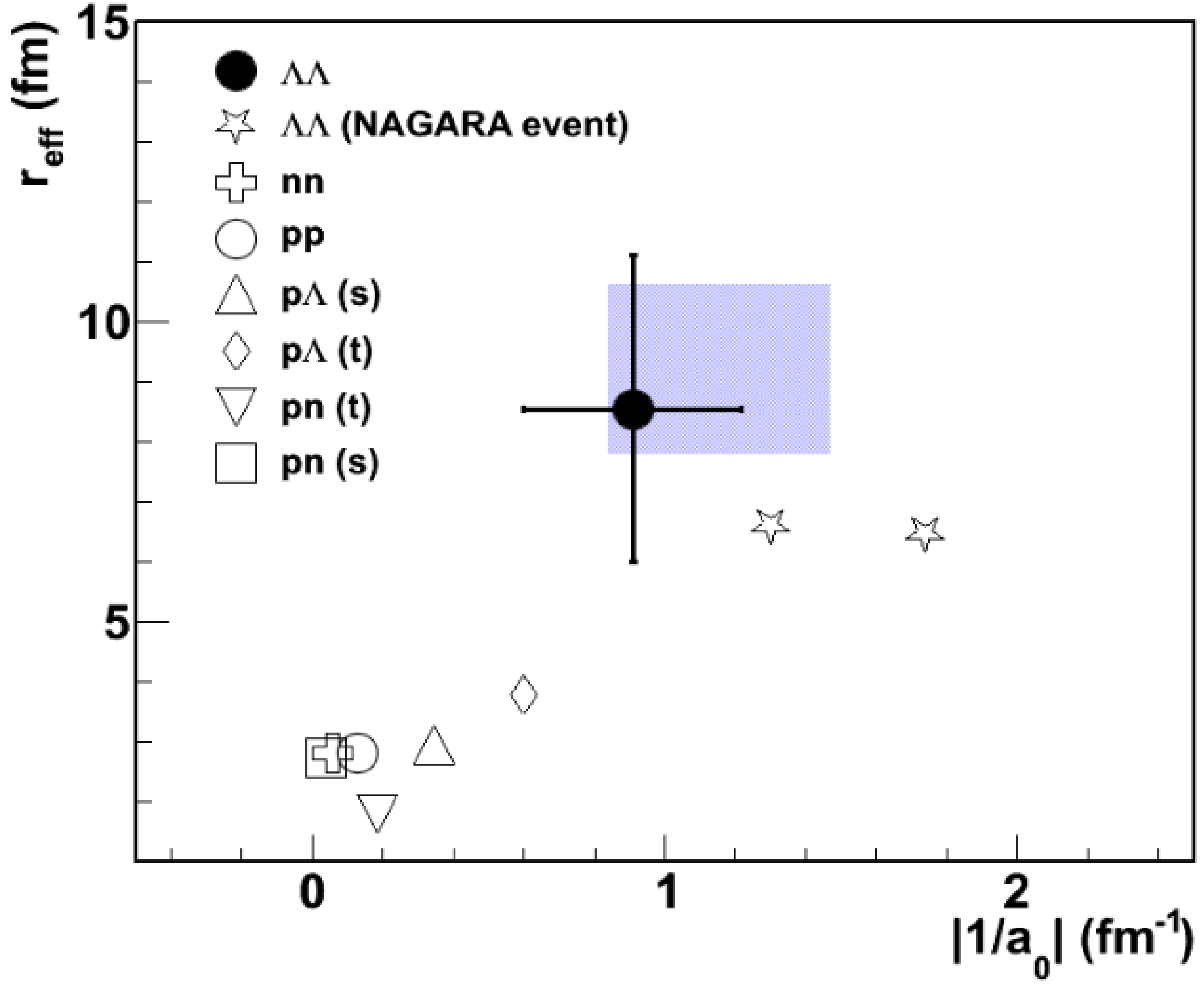
Details: http://wielanek.fizyka.pw.edu.pl/pwg3_temp/cf_proton/



Lambda – lambda correlations

Study the properties of strong interaction

Looking for exotic states of matter



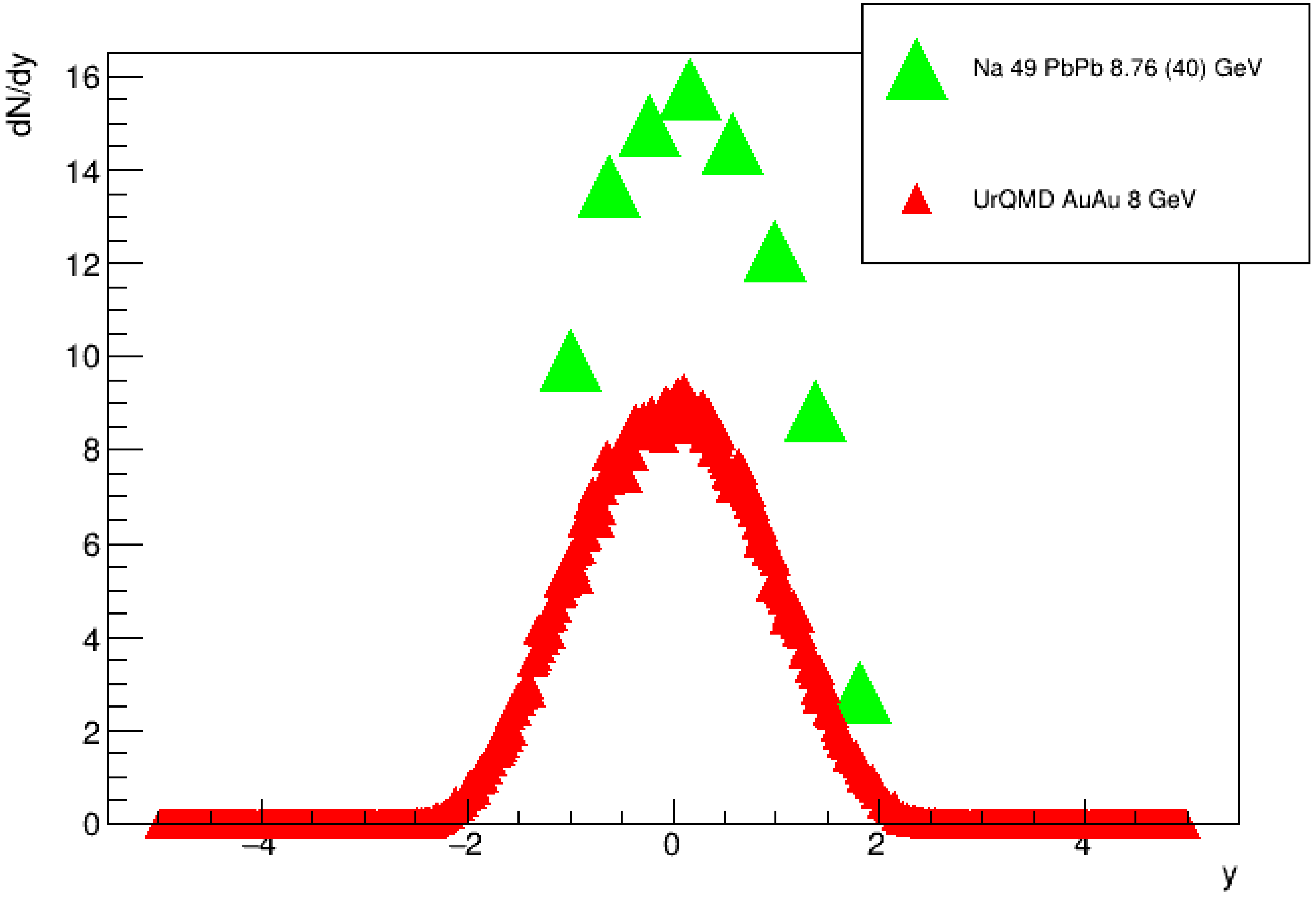
ΛΛ Correlation Function in Au+Au collisions at sNN=\sqrt{s_{NN}}=sNN = 200 GeV, *Phys.Rev.Lett.* 114 (2015) 2, 022301**, L. Adamczyk et al..**

Lambda – lambda correlations

Test of UrQMD model:

UrQMD centrality : 0-5%

Na49 centrality: 0-10%

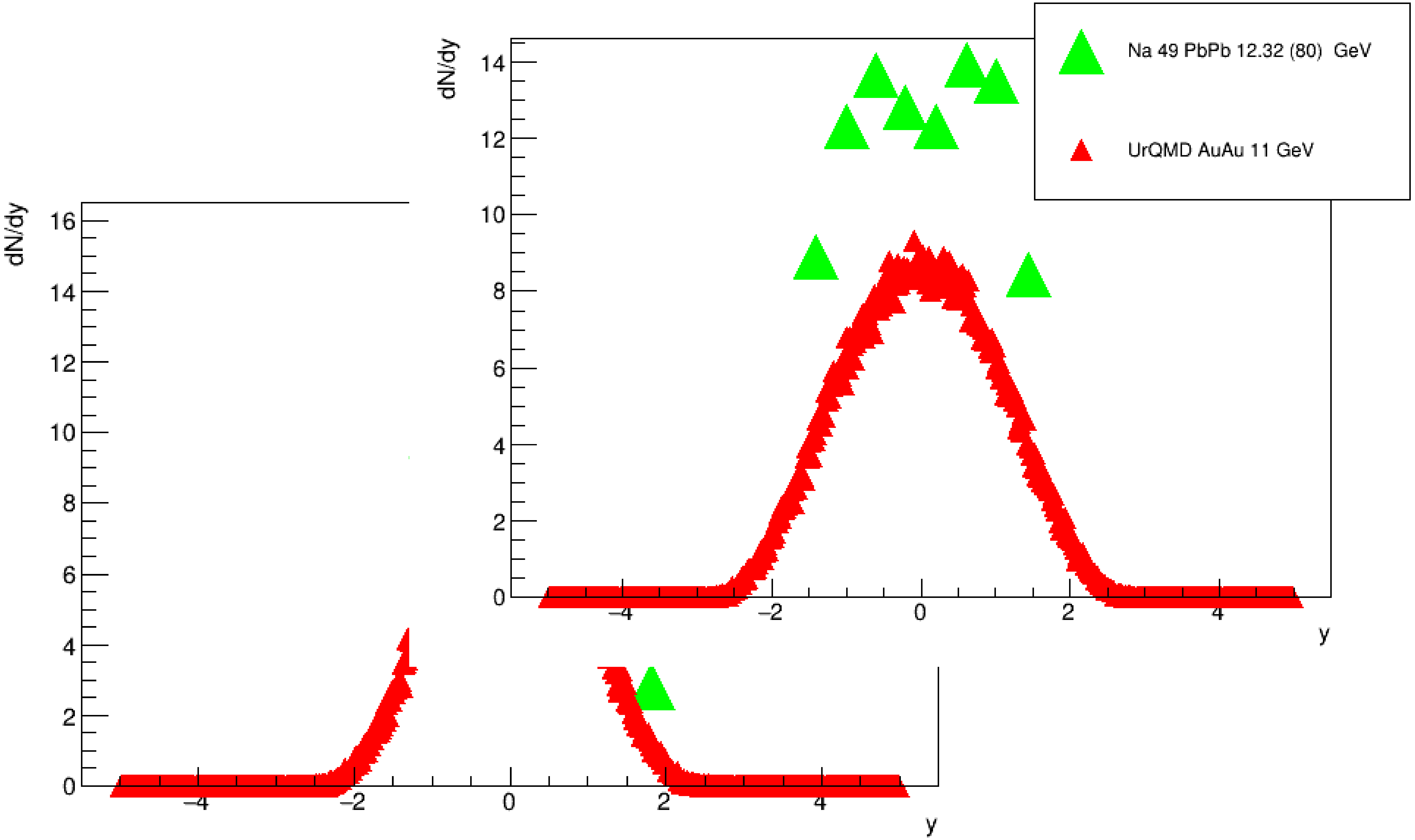


Lambda – lambda correlations

Test of UrQMD model:

UrQMD centrality : 0-5%

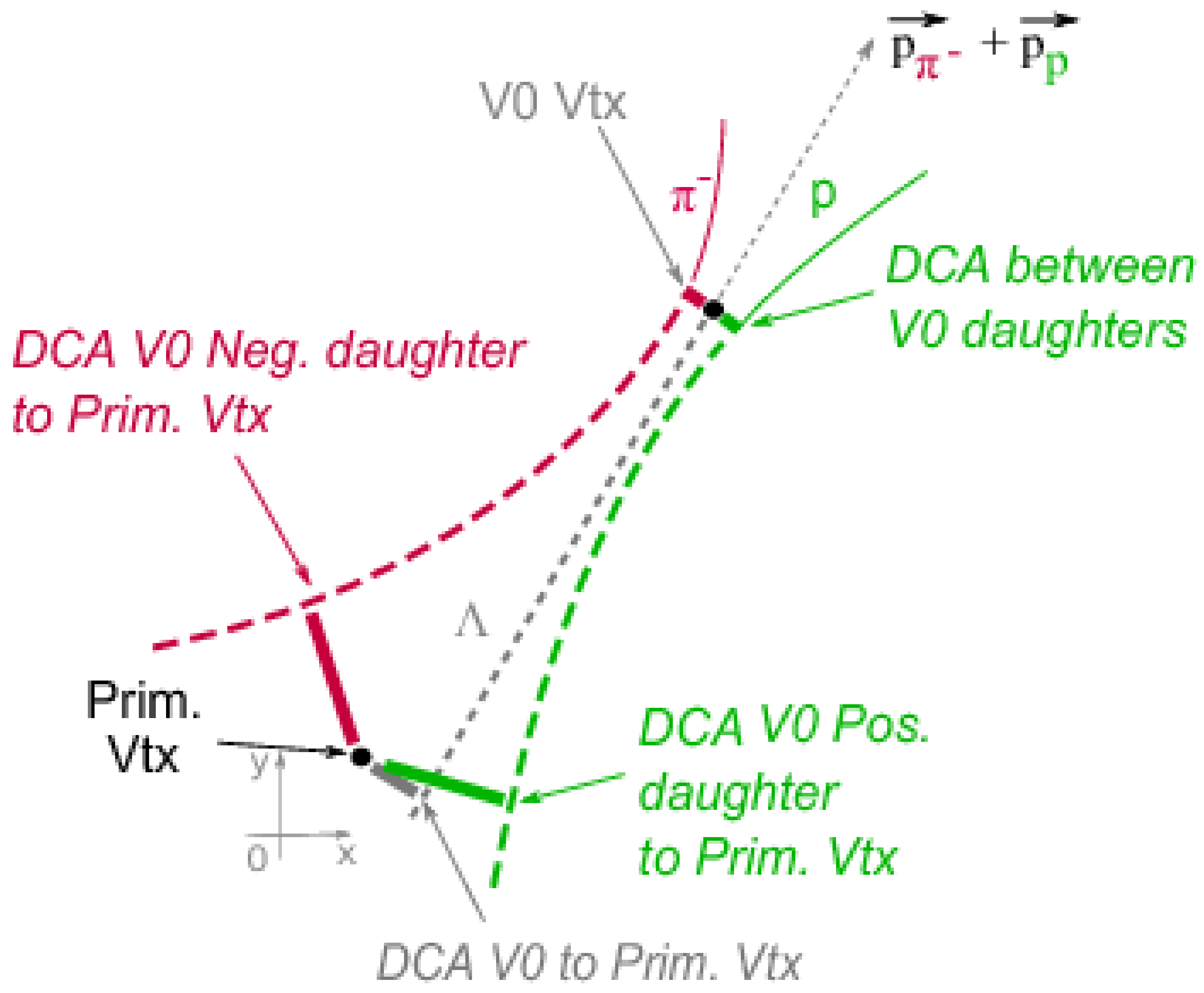
Na49 centrality: 0-10%



Lambda – lambda correlations

The possibility of extraction of Lambda particles:

- Cuts (mostly inspired by STAR):
  - 20 < hits TPC
  - 2> $|n\sigma_{proton}|$, 3> $|n\sigma_{pion}|$
  - DCA_{proton}>0.6 cm DCA_{pion}>1.5 cm
  - DCA_{pv} <0.4 cm
  - DCA_{1to2}<0.8 cm
  - Decay length > 7cm
  - $V0_{mass}$ 1.112-1.120
- Data sample:
  - 6.7 M events BiBi @ 9GeV (mass production)
- Helix model
- Link to report: http://wielanek.fizyka.pw.edu.pl/pwg3_temp/v0test/

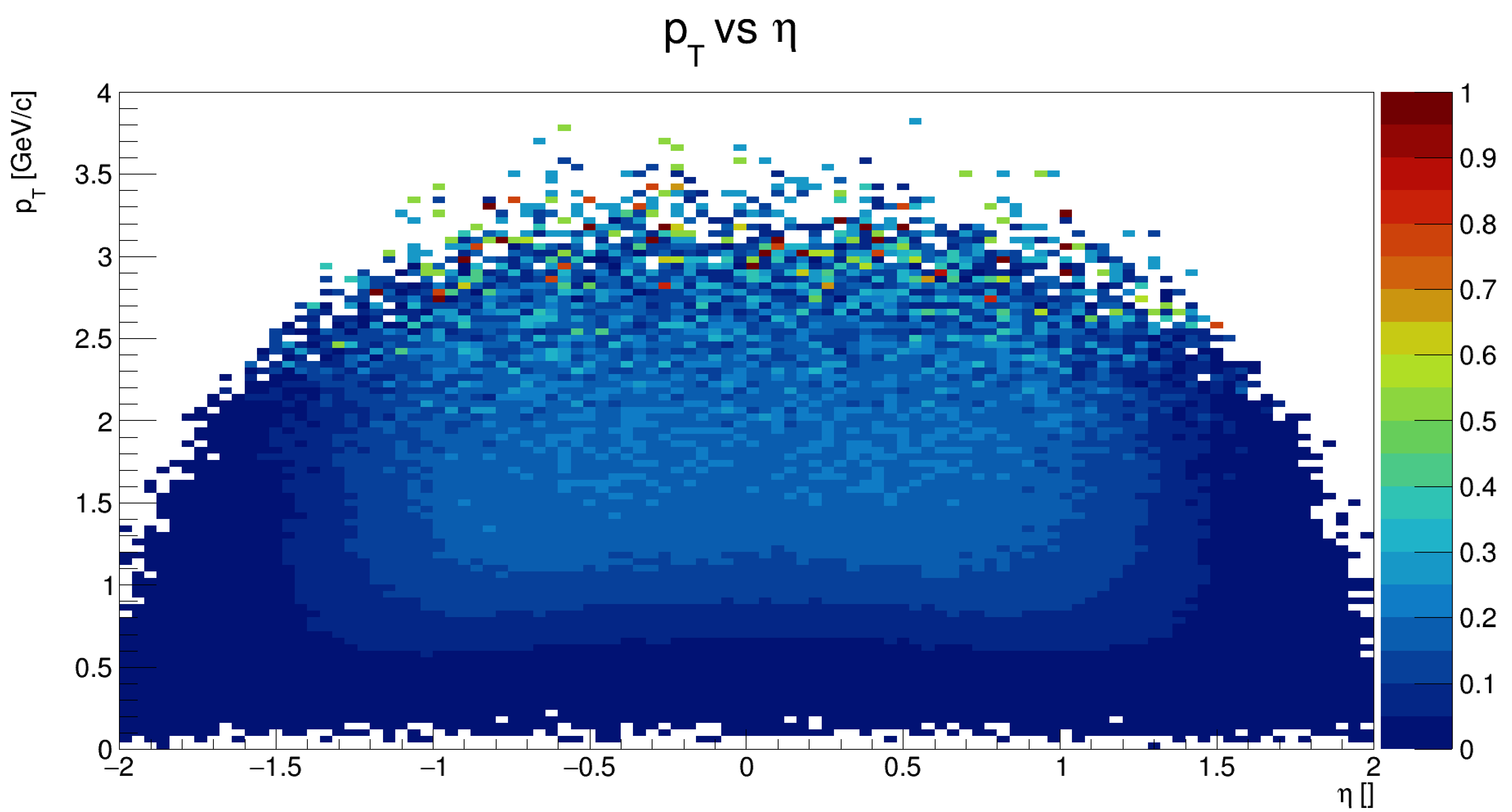


Lambda – lambda correlations

Estimated purity >90%
efficiency ~8% in kin range
$|\eta|<1$, $0.2<p_T<4$ GeV

Simulation BiBi 9 GeV central prod.

http://wielanek.fizyka.pw.edu.pl/pwg3_temp/v0test/

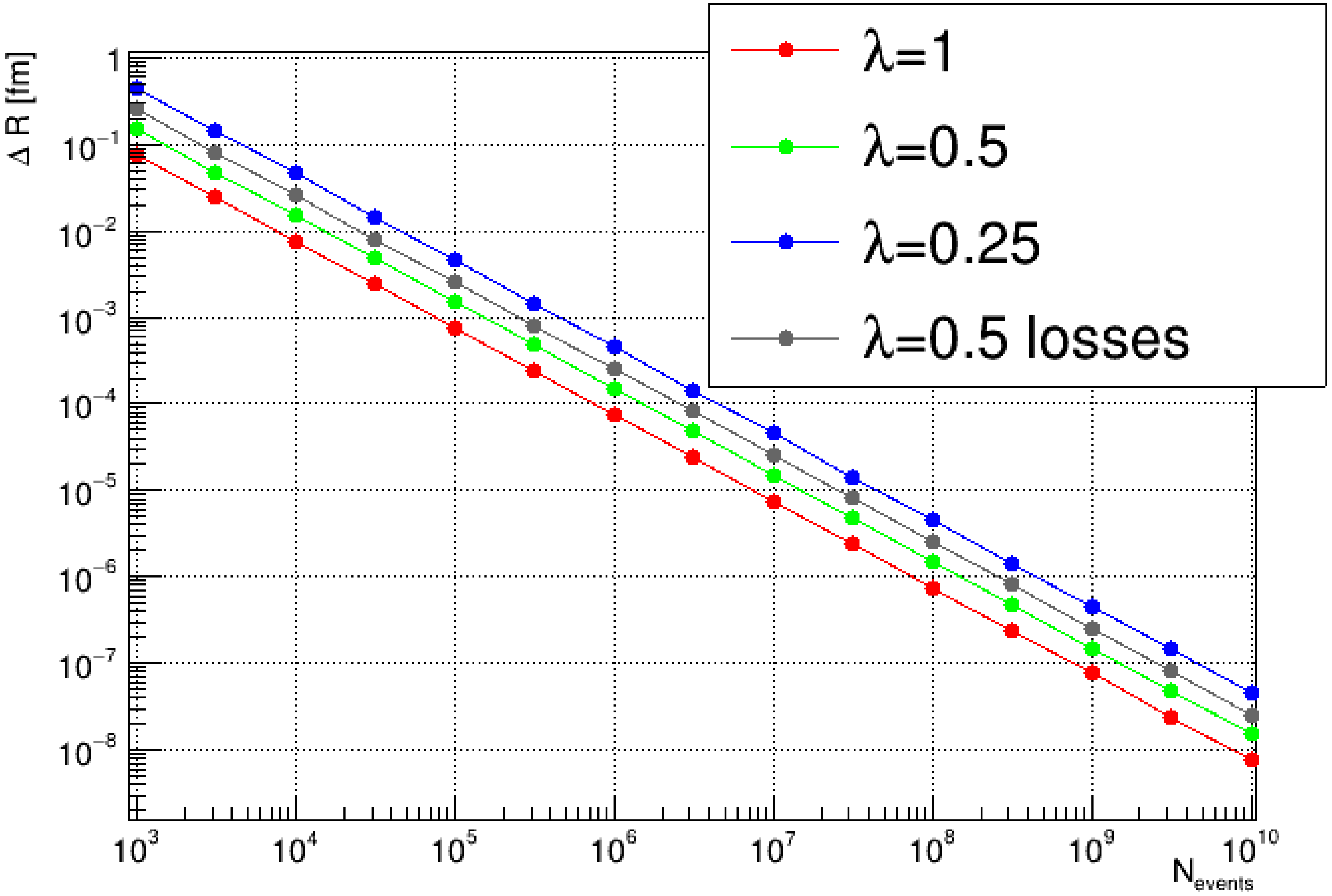


Ok let's put all stuff together:

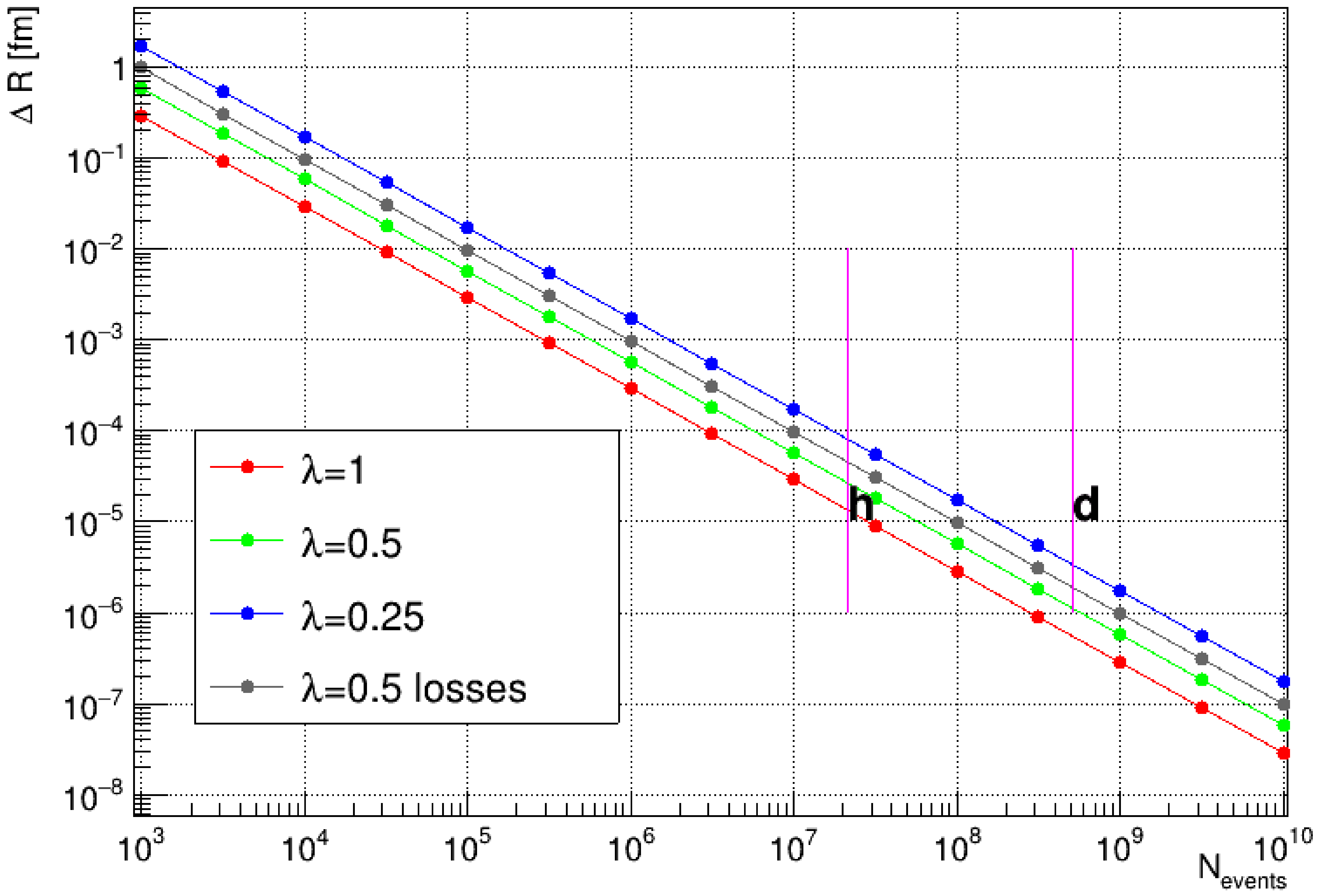
Estimation of minimumm bias events to get ONE correlation function with R=3.5 fm.

UrQMD based simulations – 1 M events, only particles from UrQMD taken into account (no weak decays)

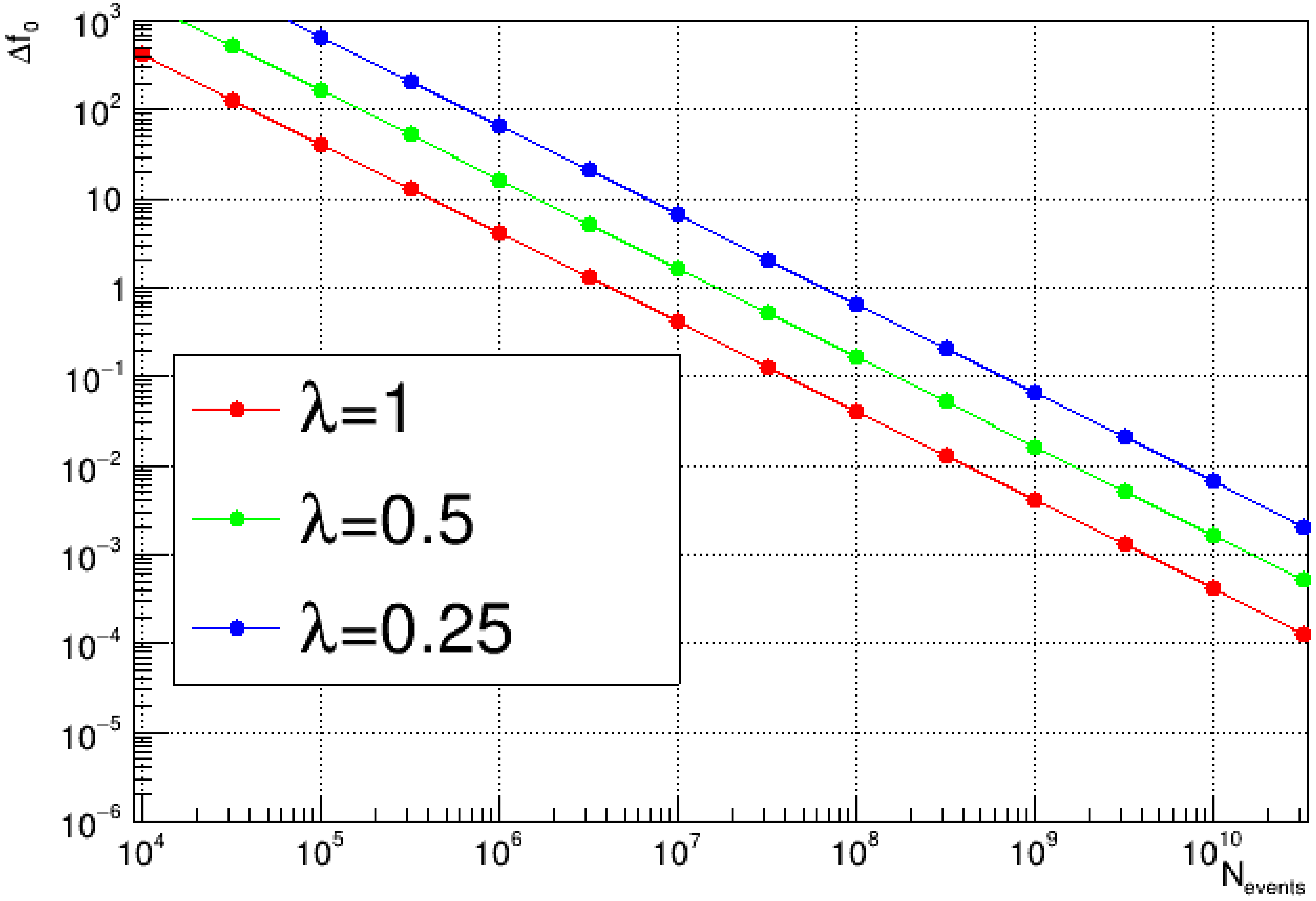
Proton-proton 4 GeV



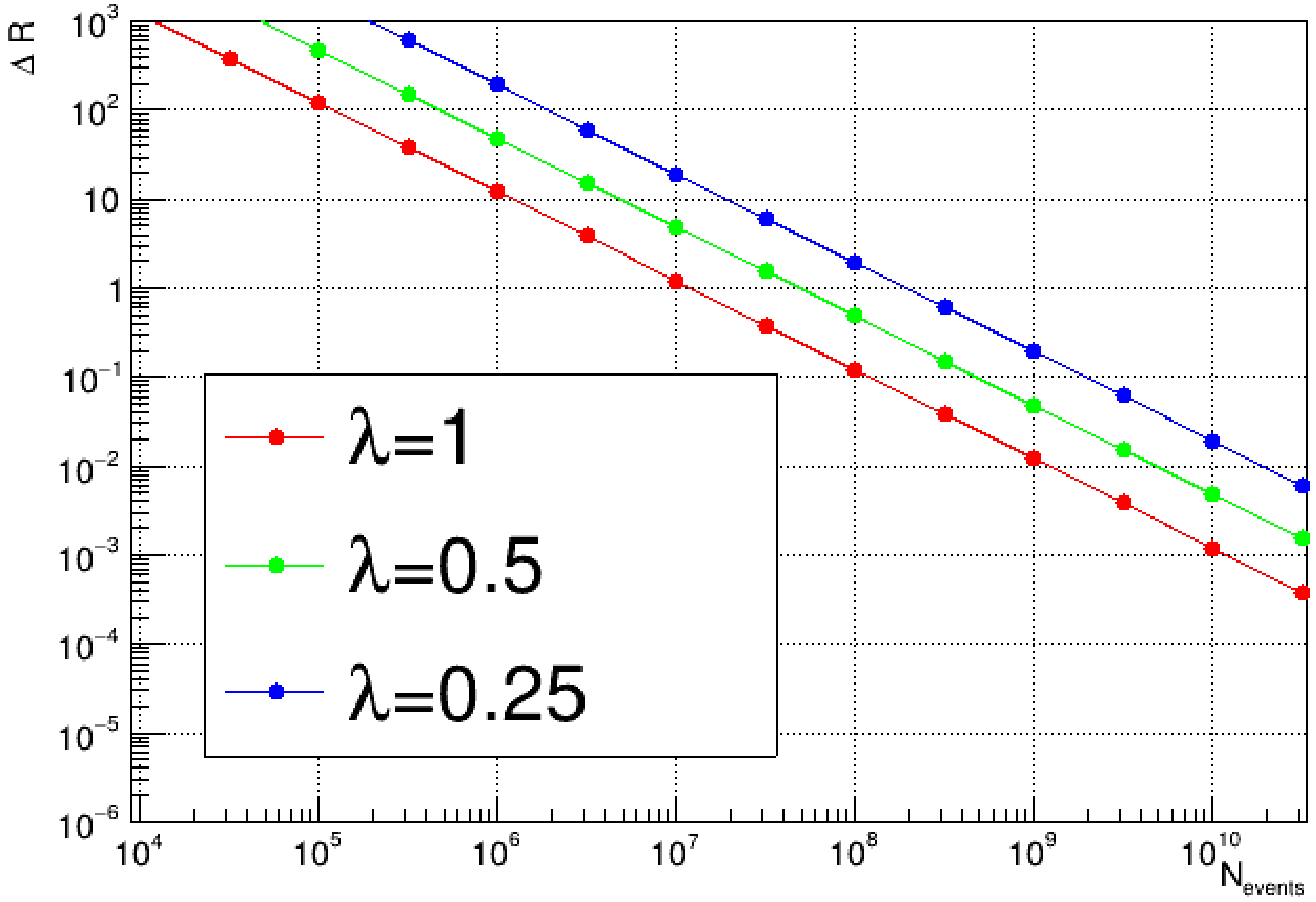
Proton-proton 11 GeV



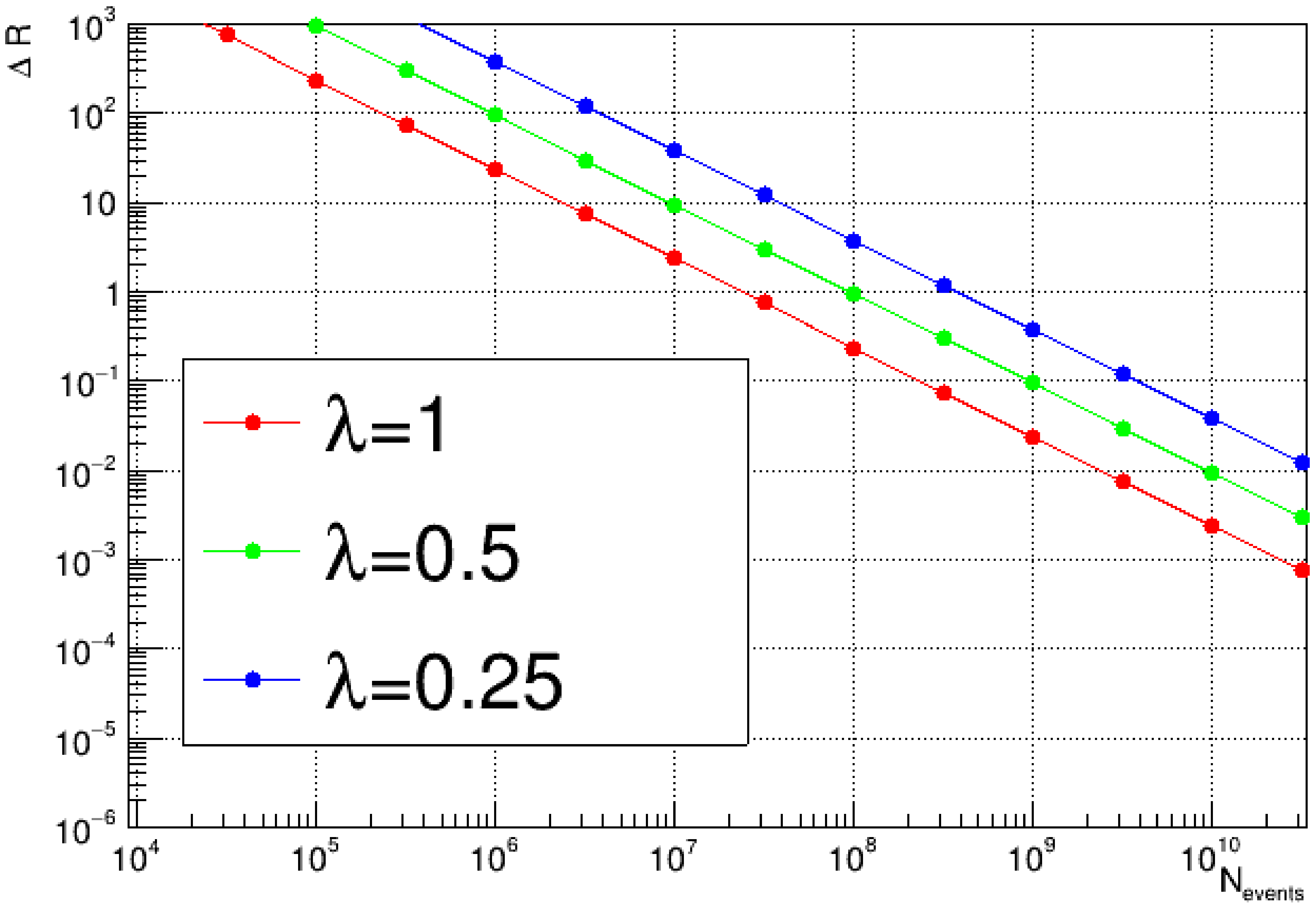
Lambda-lambda 11 GeV



Lambda-lambda 8 GeV



Lambda-lambda 4 GeV



Estimation attempt no 2.

Estimation of pairs from UrQMD with k*<0.03 GeV/c

1M of events per energy, link to analysis output:

$\sqrt{s_{NN}}$= 4 http://wielanek.fizyka.pw.edu.pl/pwg3_temp/uboot_4/

$\sqrt{s_{NN}}$= 6 http://wielanek.fizyka.pw.edu.pl/pwg3_temp/uboot_6/

$\sqrt{s_{NN}}$= 8 http://wielanek.fizyka.pw.edu.pl/pwg3_temp/uboot_8/

$\sqrt{s_{NN}}$= 11 http://wielanek.fizyka.pw.edu.pl/pwg3_temp/uboot_11/

Cuts:

$0.4<p_T<4$ GeV/c

$|\eta|<1$

Number of pairs multiplied by 10^6 4 GeV:

Centrality	Proton-proton	Lambda-lambda	Proton-Lambda	Proton-antiproton
Minimum bias	19 506+/- 140	72+/- 8	2 252+/-47	0+/- 0
0-10%	116 504+/-1082	442+/-67	14 373+/- 380	0+/- 0
10-20%	50 043+/- 722	219+/-48	5 675+/- 243	0+/- 0
20-30%	20 069+/- 439	67+/-25	1 757+/- 130	0+/- 0

Number of pairs multiplied by 10^6 6 GeV:

Centrality	Proton-proton	Lambda-lambda	Proton-Lambda	Proton-antiproton
Minimum bias	10 578+/- 103	135+/-12	2 250+/-47	21+/- 5
0-10%	65 434+/- 807	866+/-93	14 582+/- 381	129+/-36
10-20%	25 385+/- 513	321+/-58	5 065+/- 229	31+/-18
20-30%	10 335+/- 316	116+/-33	2 202+/- 146	19+/-14

Number of pairs multiplied by 10^6 8 GeV:

Centrality	Proton-proton	Lambda-lambda	Proton-Lambda	Proton-antiproton
Minimum bias	7 249+/-85	143+/-12	1 979+/-44	80+/- 9
0-10%	45 760+/- 677	981+/-99	12 808+/- 358	400+/-63
10-20%	17 141+/- 422	332+/-59	4 565+/- 218	176+/-43
20-30%	6 992+/- 260	58+/-24	1 676+/- 127	116+/-33

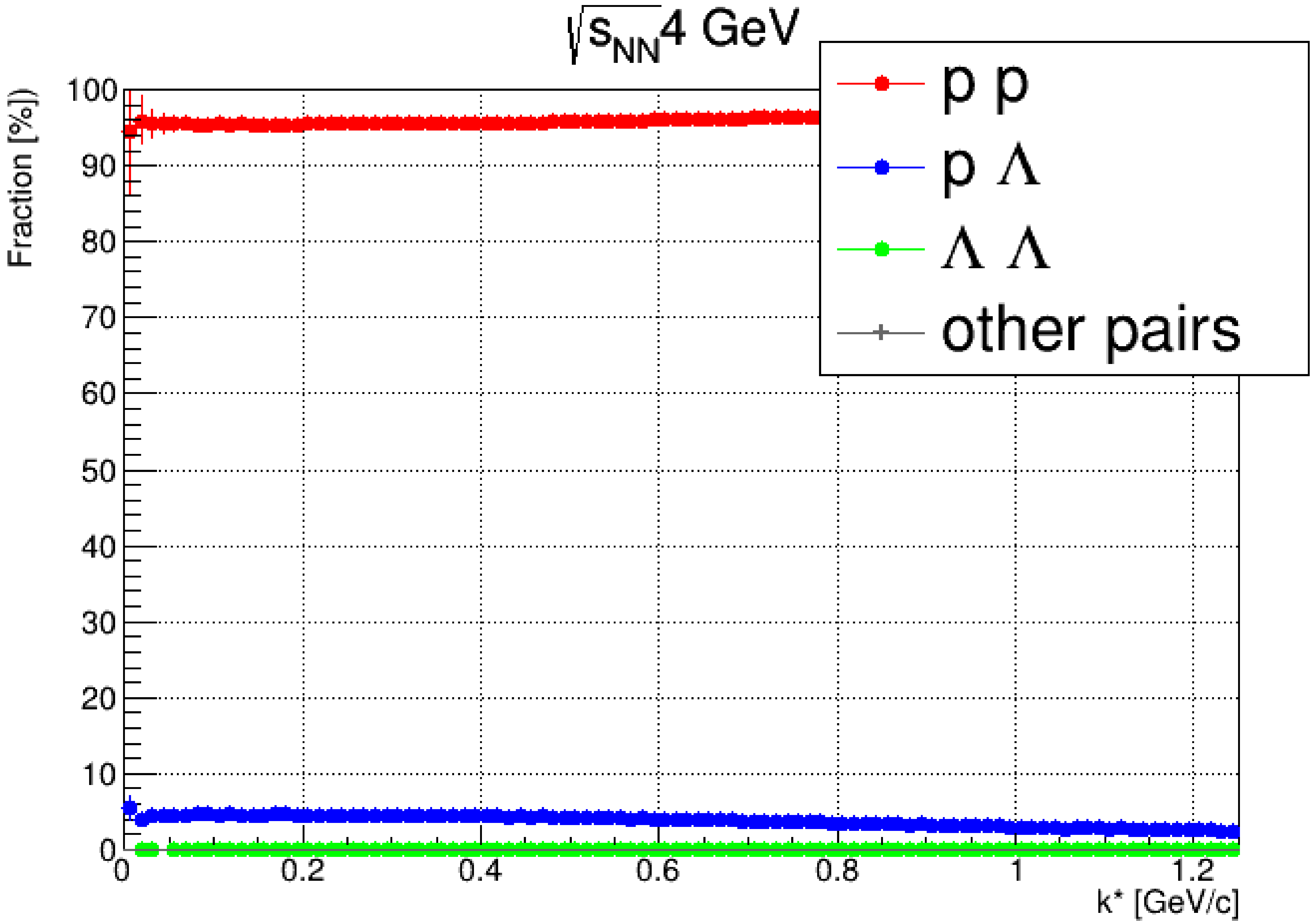
Number of pairs multiplied by 10^6 11 GeV:

Centrality	Proton-proton	Lambda-lambda	Proton-Lambda	Proton-antiproton
Minimum bias	5 124+/-72	141+/-12	1 572+/-40	186+/-14
0-10%	32 200+/- 566	956+/-98	10 069+/- 317	986+/-99
10-20%	12 270+/- 357	353+/-61	3 841+/- 200	457+/-69
20-30%	4 728+/- 214	68+/-26	1 344+/- 114	232+/-47

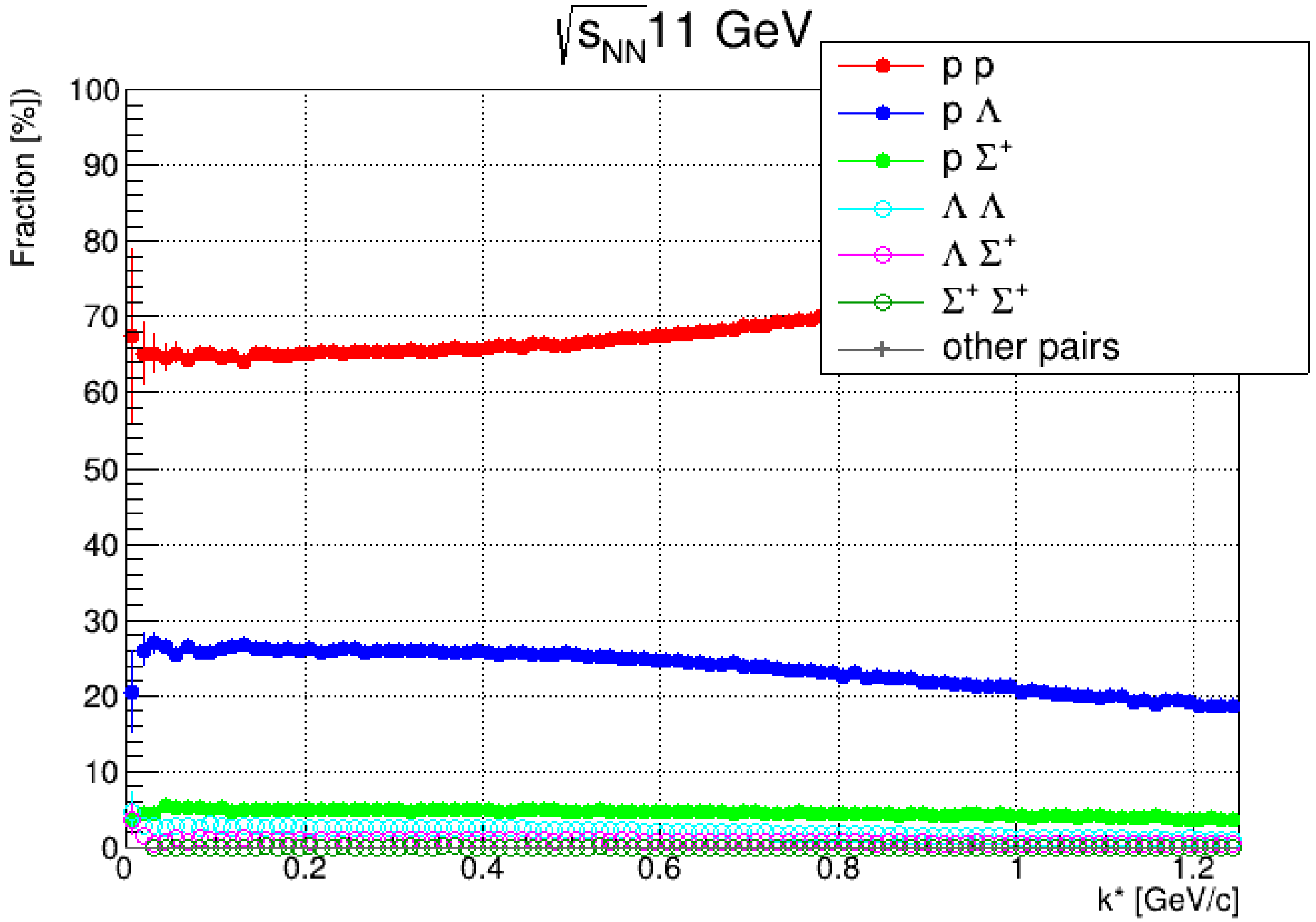
Centrality	Proton-proton	Lambda-lambda	Proton-Lambda	Proton-antiproton
Minimum bias	19 506+/- 140	72+/- 8	2 252+/-47	0+/- 0
0-10%	116 504+/-1082	442+/-67	14 373+/- 380	0+/- 0
10-20%	50 043+/- 722	219+/-48	5 675+/- 243	0+/- 0
20-30%	20 069+/- 439	67+/-25	1 757+/- 130	0+/- 0

sNN=4GeV

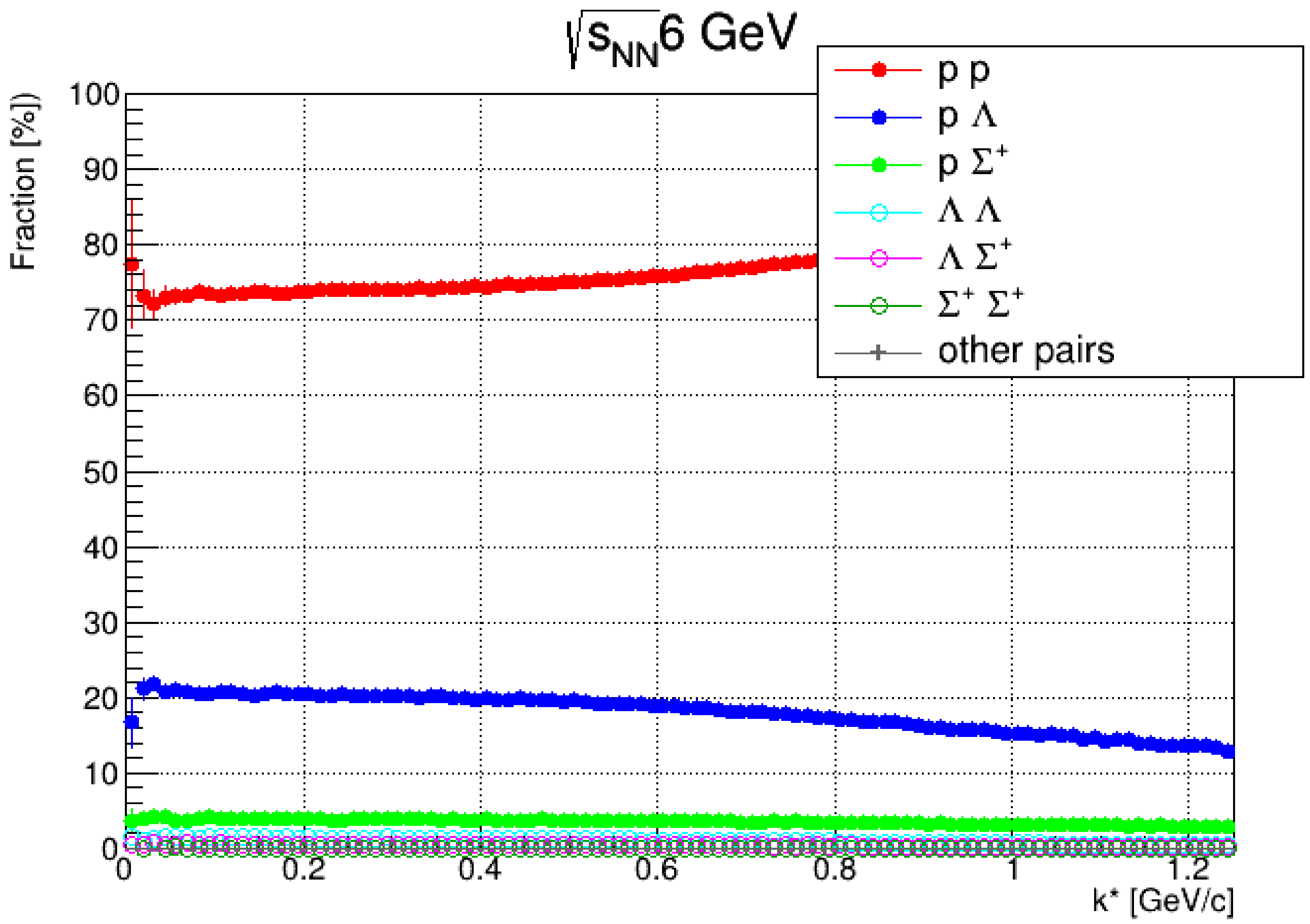
Residual correlations



Residual correlations



Residual correlations



Summary

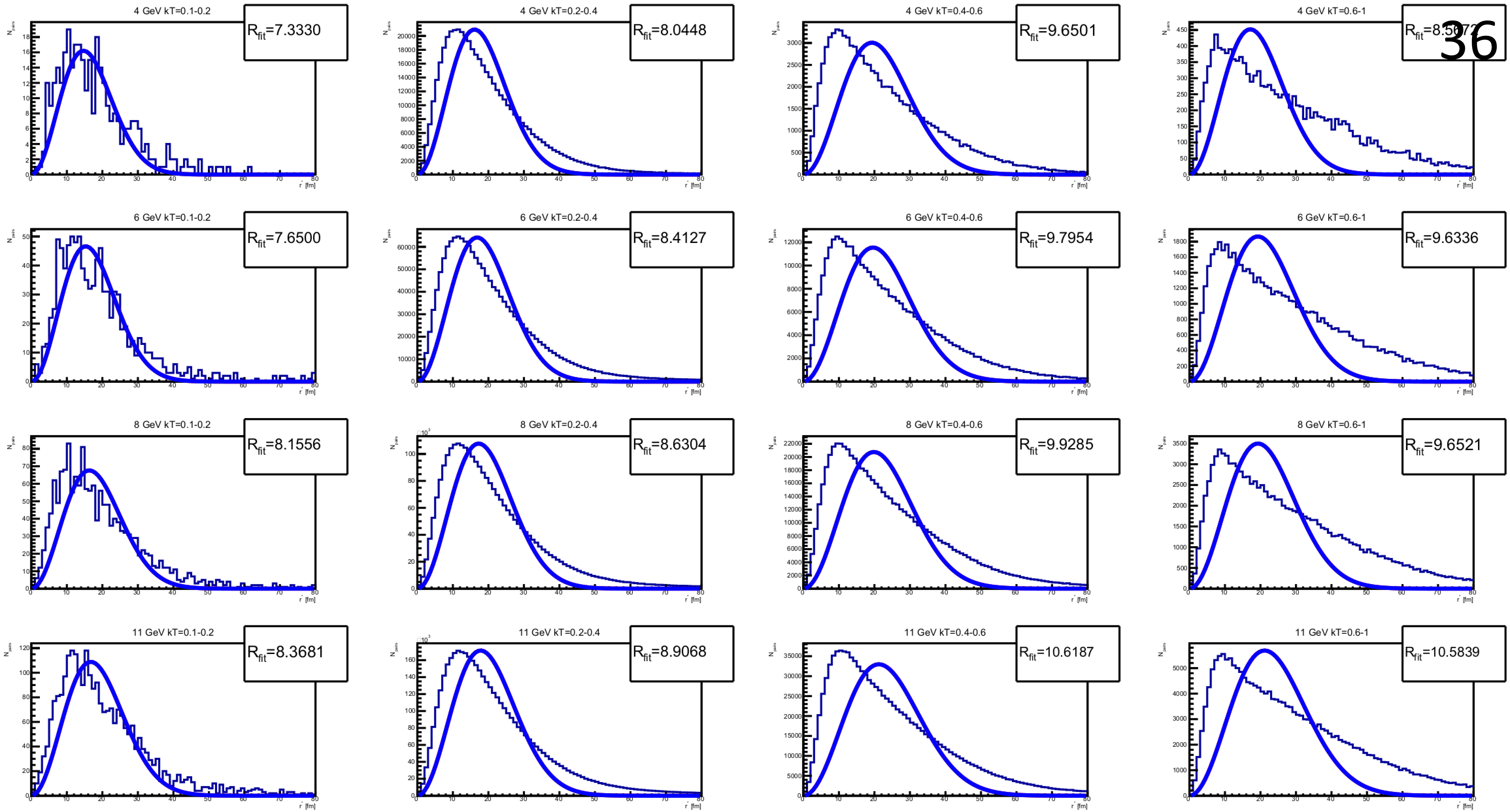
Conclusions:

- first estimation of needed statistic is completed
- Promising results for proton-proton measurements

Plans:

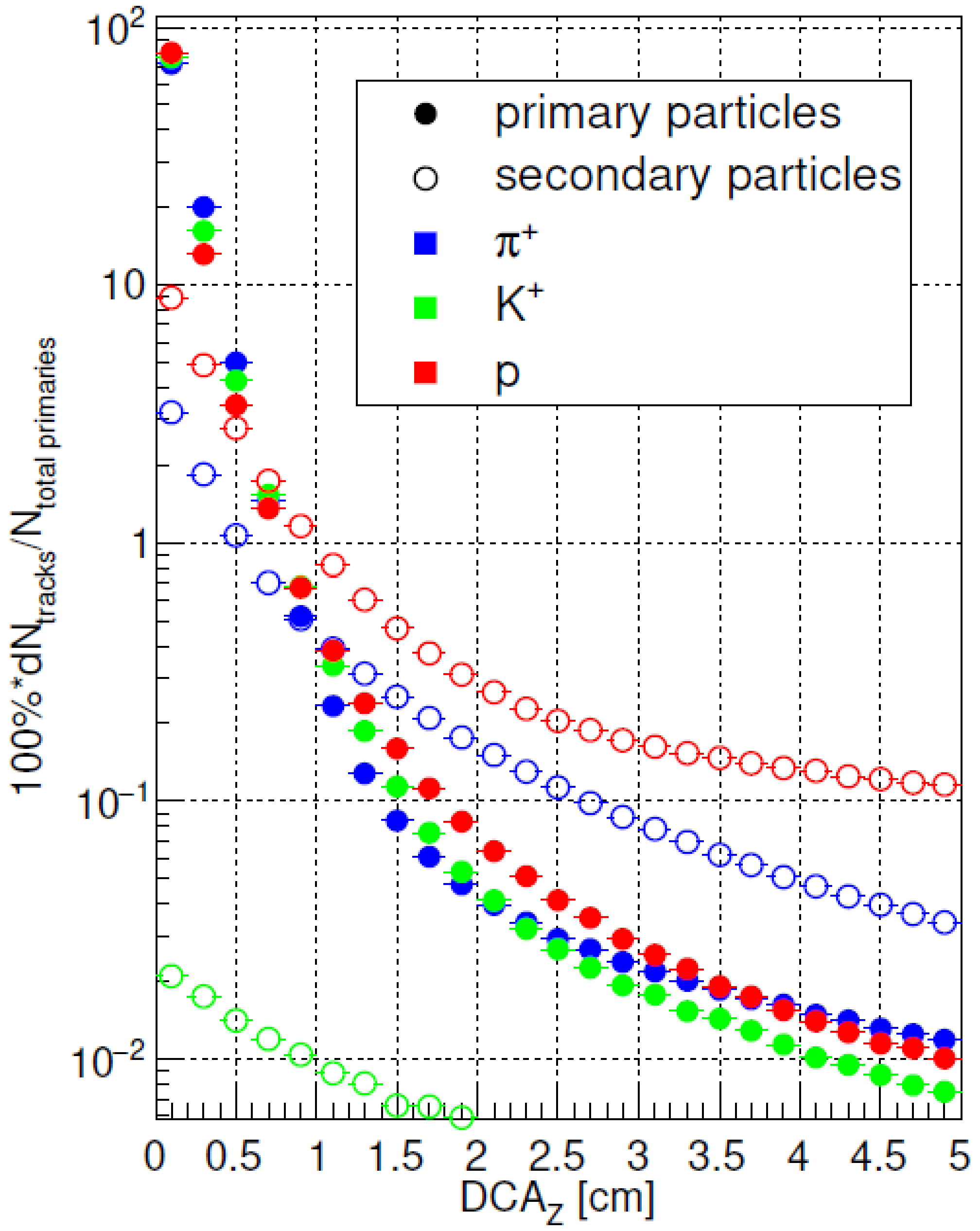
- studies with different models (vHLLE, PHSD ...)
- study of detector performance (splitting, merging, selection of primary/secondary particles)
- estimation of systematic uncertainty
- further development of NicaCorrFit

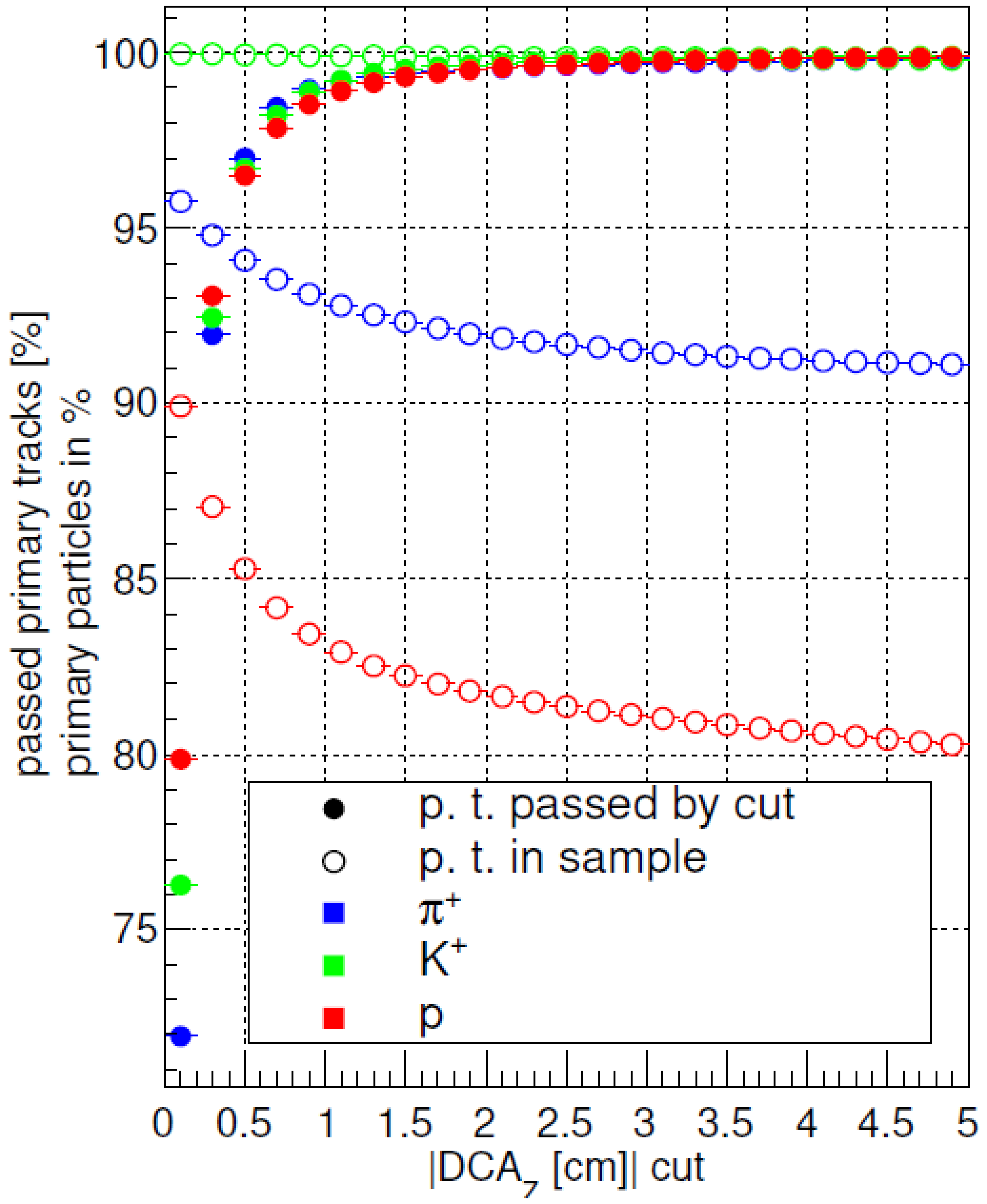
Thank you for your attention

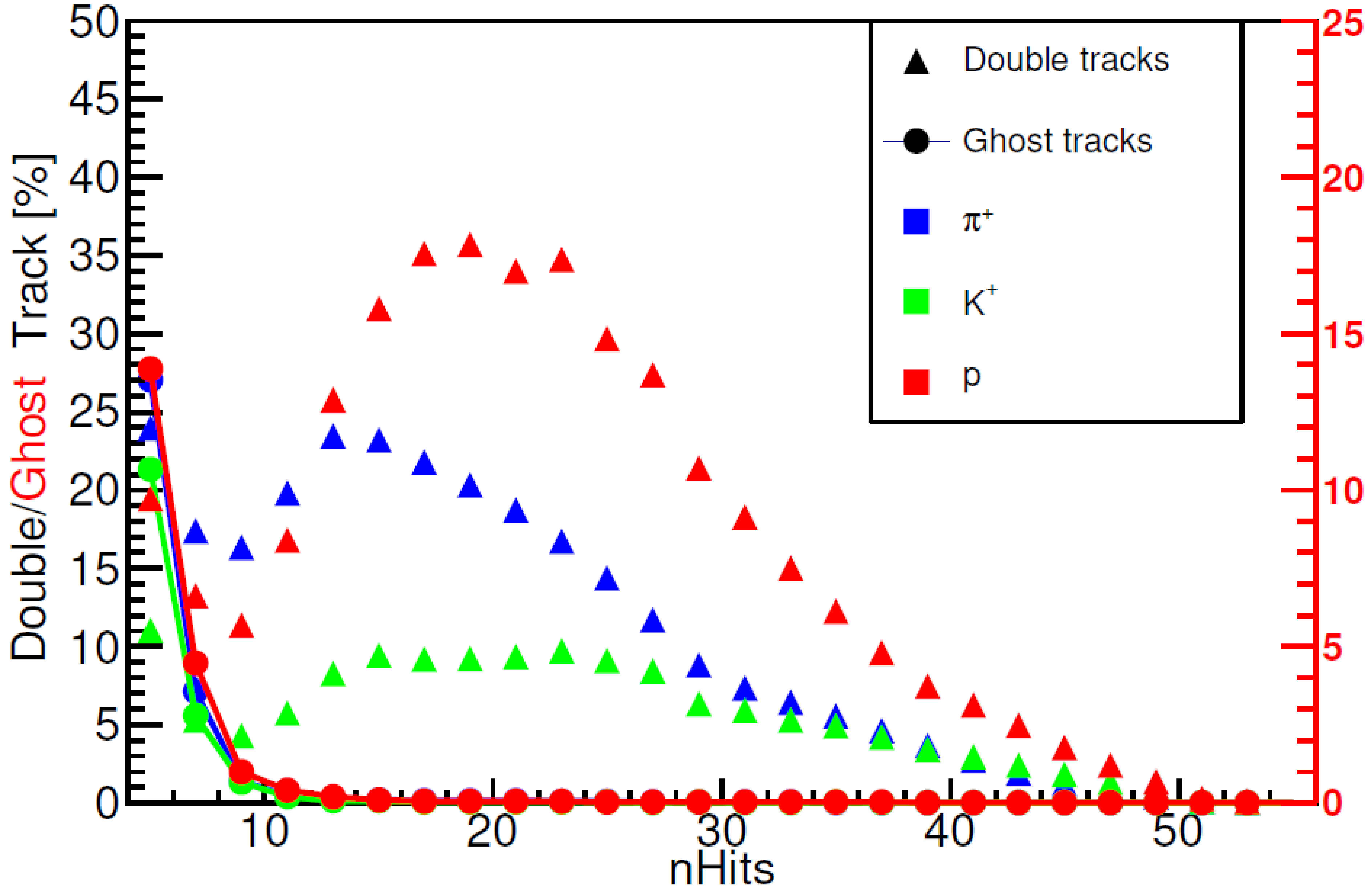

4 GeV kT=0.1-0.2
Rfit=7.3330
4 GeV kT=0.2-0.4
Rfit=8.0448
4 GeV kT=0.4-0.6
Rfit=9.6501
4 GeV kT=0.6-1
6 GeV kT=0.1-0.2
Rfit=7.6500
6 GeV kT=0.2-0.4
Rfit=8.4127
6 GeV kT=0.4-0.6
Rfit=9.7954
6 GeV kT=0.6-1
Rfit=9.6336
8 GeV kT=0.1-0.2
Rfit=8.1556
8 GeV kT=0.2-0.4
Rfit=8.6304
8 GeV kT=0.4-0.6
Rfit=9.9285
8 GeV kT=0.6-1
Rfit=9.6521
11 GeV kT=0.1-0.2
Rfit=8.3681
11 GeV kT=0.2-0.4
Rfit=8.9068
11 GeV kT=0.4-0.6
Rfit=10.6187
11 GeV kT=0.6-1
Rfit=10.5839

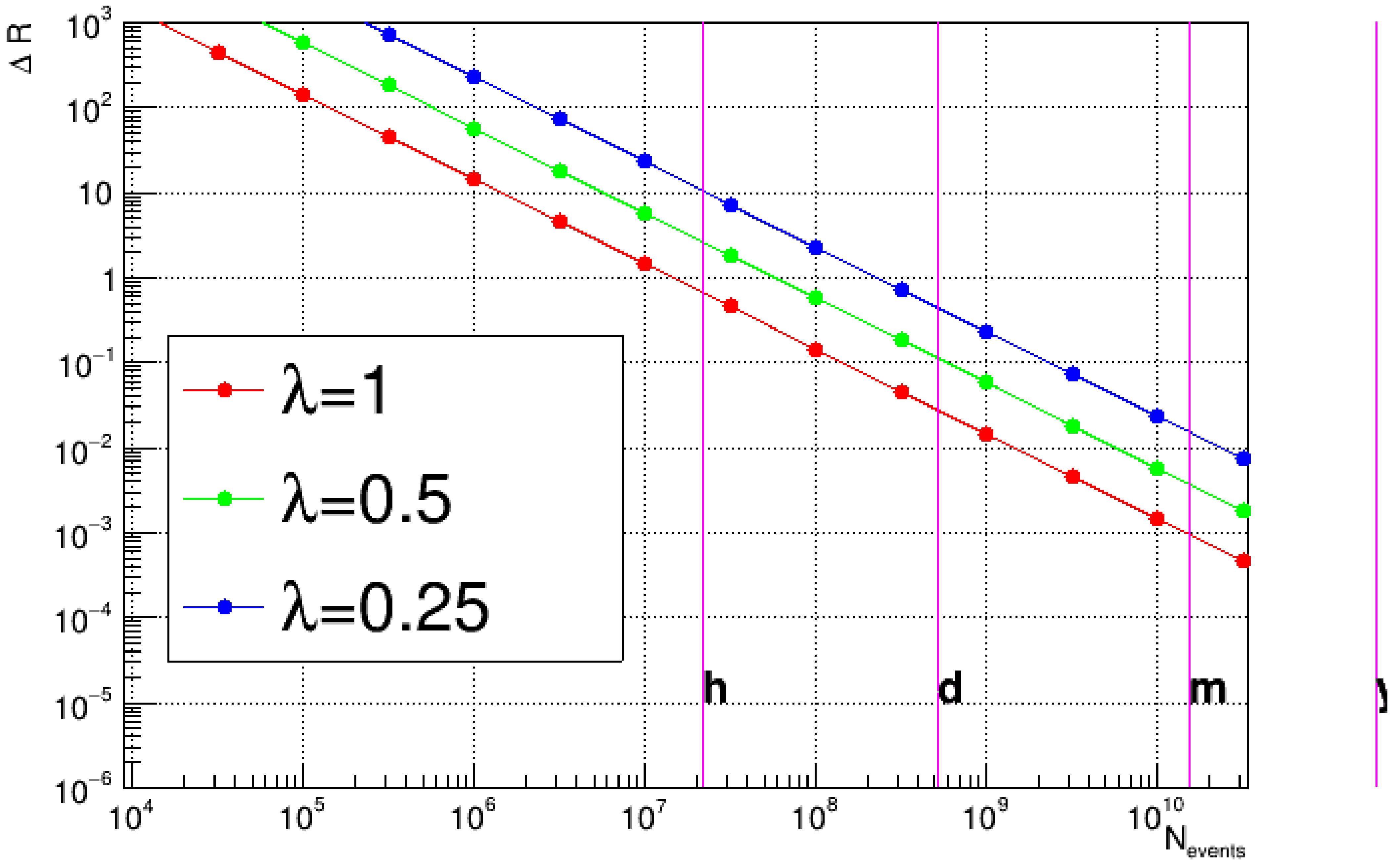
Femtoscopy of protons

Cuts were optimized for AuAu collisions from old data (201









Δ R
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^4
10^5
10^6
10^7
10^8
10^9
10^{10}
N_{events}
λ=1
λ=0.5
λ=0.25
h
d
m