Progress in $\bar{\Lambda}$ reconstruction

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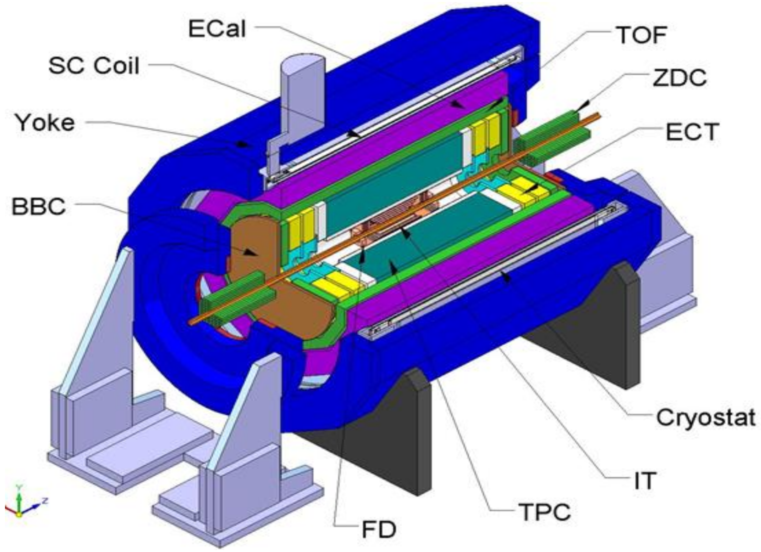
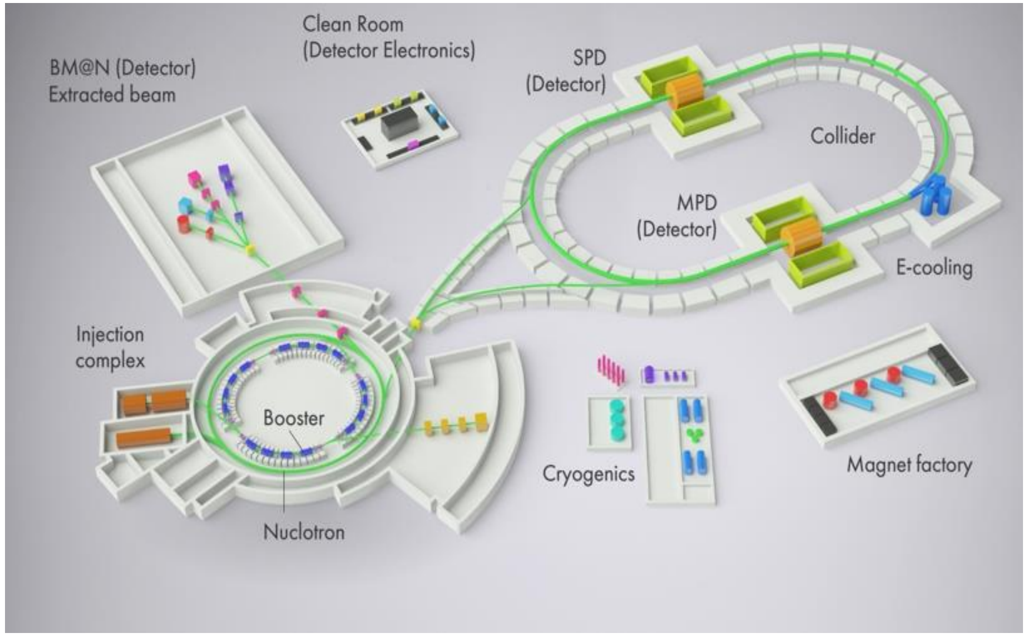
03.06.2021

Motivation



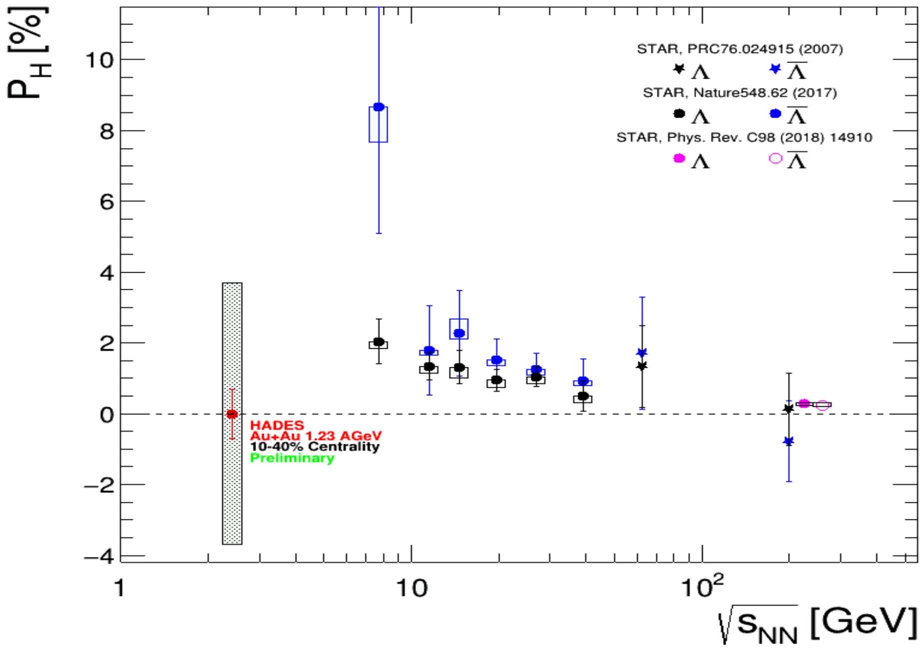
Hyperons can provide essential signatures of the hot and compressed baryonic matter

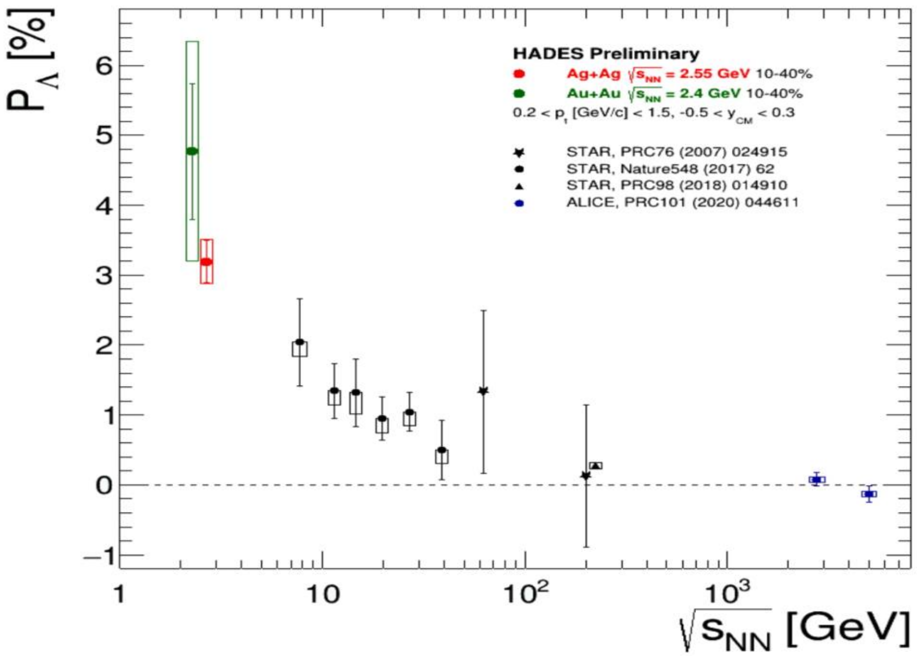
At NICA it is planned to study hyperons at MPD and BM@N setup



In heavy ion collisions measurement of strange hyperons polarization allows to research properties of the QCD medium (vorticity, hydrodynamic helicity)

Motivation





Predicted[1] and observed[2] global polarization signals rise as the collision energy is reduced

NICA energy range will provide new insight

- Large $\Lambda(\bar{\Lambda})$ splitting observed at low energies (RHIC)
- Updated result from HADES follows the increasing trend[3]

1. O. Rogachevsky, A. Sorin, O. Teryaev, Phys.Rev. C 82, 054910 (2010)

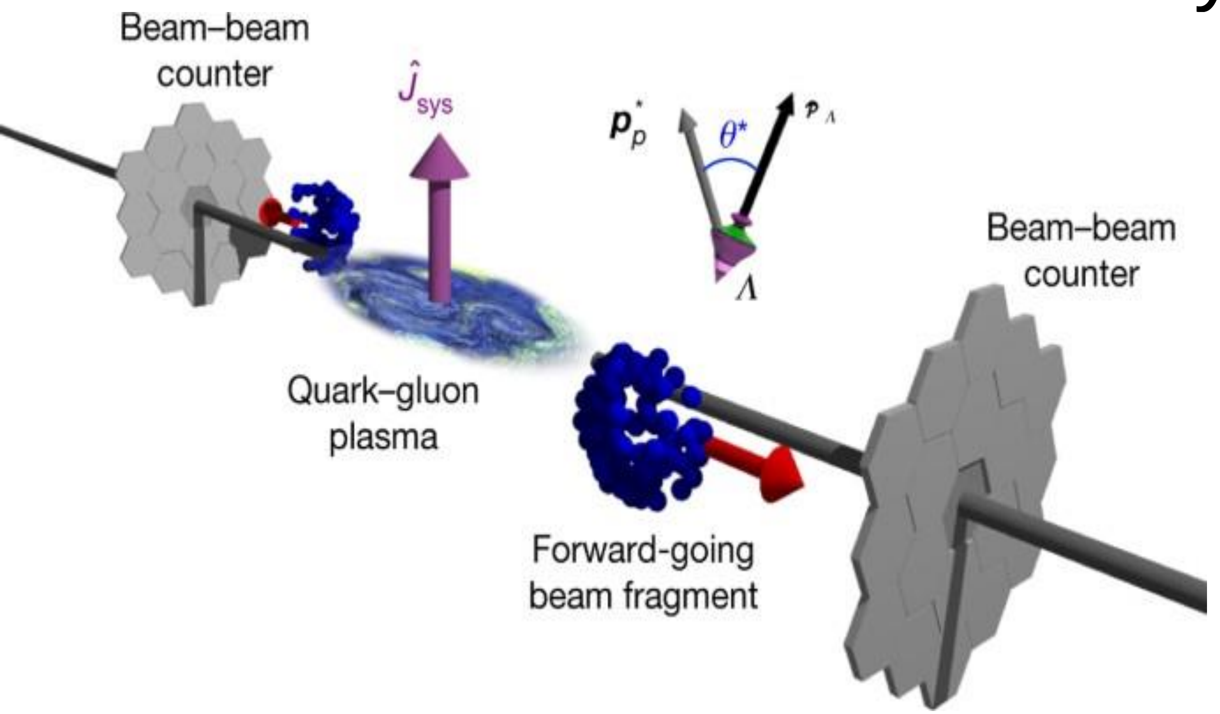
2. J. Adam et al. (STAR Collaboration), Phys. Rev. C 98, 014910 (2018)

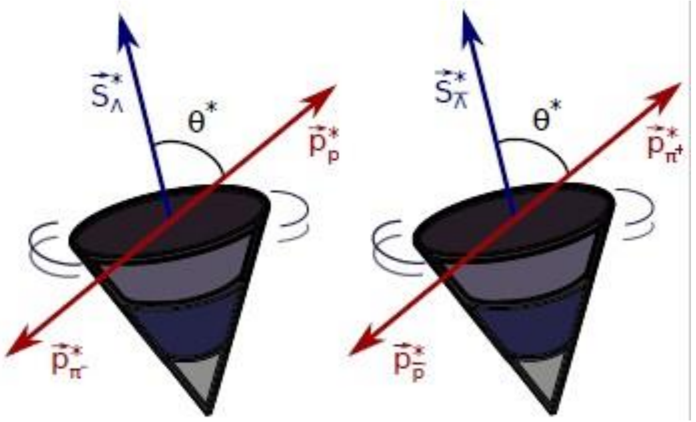
3. F. Kornas for the HADES Collaboration, SQM 2019, Bari, Italy (11.06.19)

Data

- 1400000 MB events (studied centrality intervals 0-10%, 10-20%, 20-50%, 50-100%)
- PHSD for generation
- Au Au collision at 7.7 GeV

$\bar{\Lambda} - \Lambda$ hyperon polarization





Polarization can be measured through weak deca

$$\Lambda \to p + \pi^-$$

$$\bar{\Lambda} \to \bar{p} + \pi^+$$

Angular distribution:

$$\frac{dN}{d\cos\theta} = 1 + \alpha_\Lambda P_\Lambda \cos\theta^*$$

$\alpha_\Lambda = -\alpha_{\bar{\Lambda}} = 0.750 \pm 0{,}009 \pm 0.004$ decay asymmetry parameter

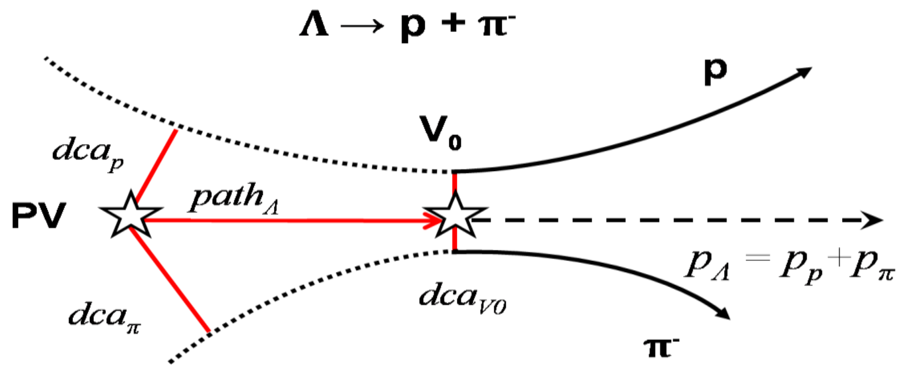
$\alpha_\Lambda = -\alpha_{\bar{\Lambda}} \approx 0.642$ (old)

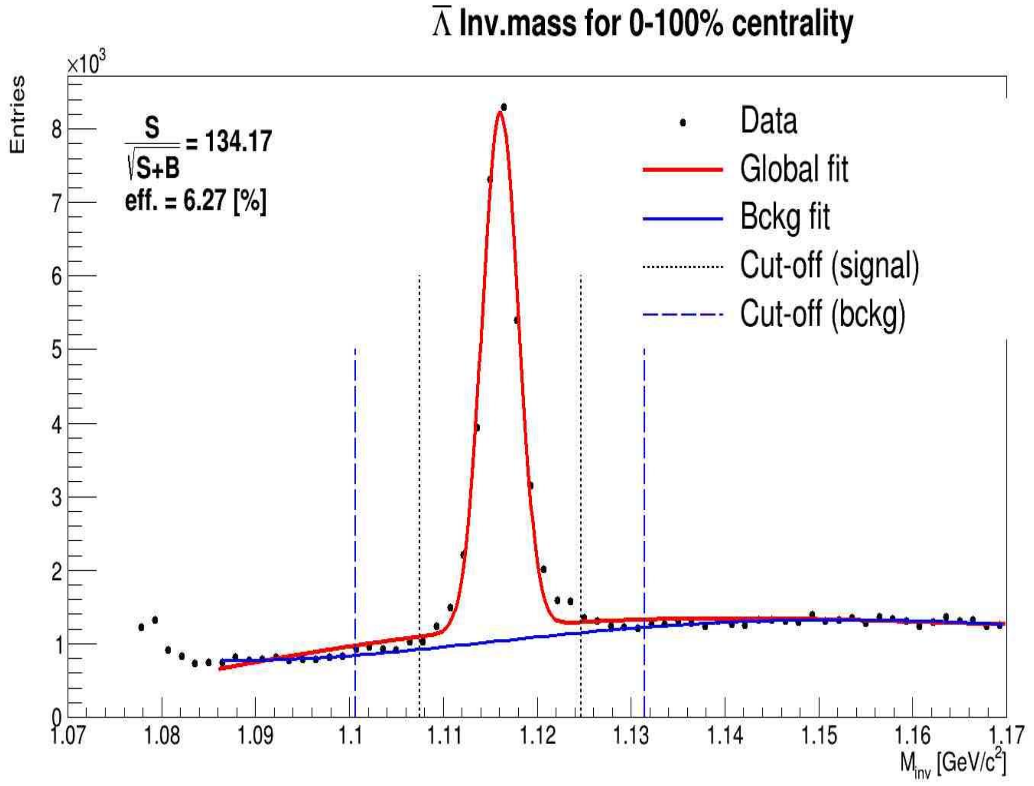
$\alpha_\Lambda = -\alpha_{\bar{\Lambda}} \approx 0.750$ (new)

Global polarization can be measured as:

$$P_\Lambda = \frac{8}{\pi\alpha_\Lambda}\frac{1}{R_{EP}}\langle \sin(\Psi_{EP} - \varphi^*)\rangle$$

$\bar{\Lambda} - \Lambda$ hyperon reconstruction technique





PV – primary vertex

V_0 – vertex of hyperon decay

dca – distance of the closest approach

path – decay length

parameters for selection: $\varpi_1 = ln\frac{dca_\pi dca_p}{dca_\Lambda^2 + dca_{V_0}^2}$

All the parameters can also be normalized to their respective errors giving a set of χ^2

$$\varpi_2 = ln\frac{\sqrt{\chi_\pi^2 \chi_p^2}}{\chi_\Lambda^2 + \chi_{V_0}^2}$$

takes into account correlations of standard selection criteria taken in χ^2

Selection cuts for inv.mass Λ, $\bar{\Lambda}$

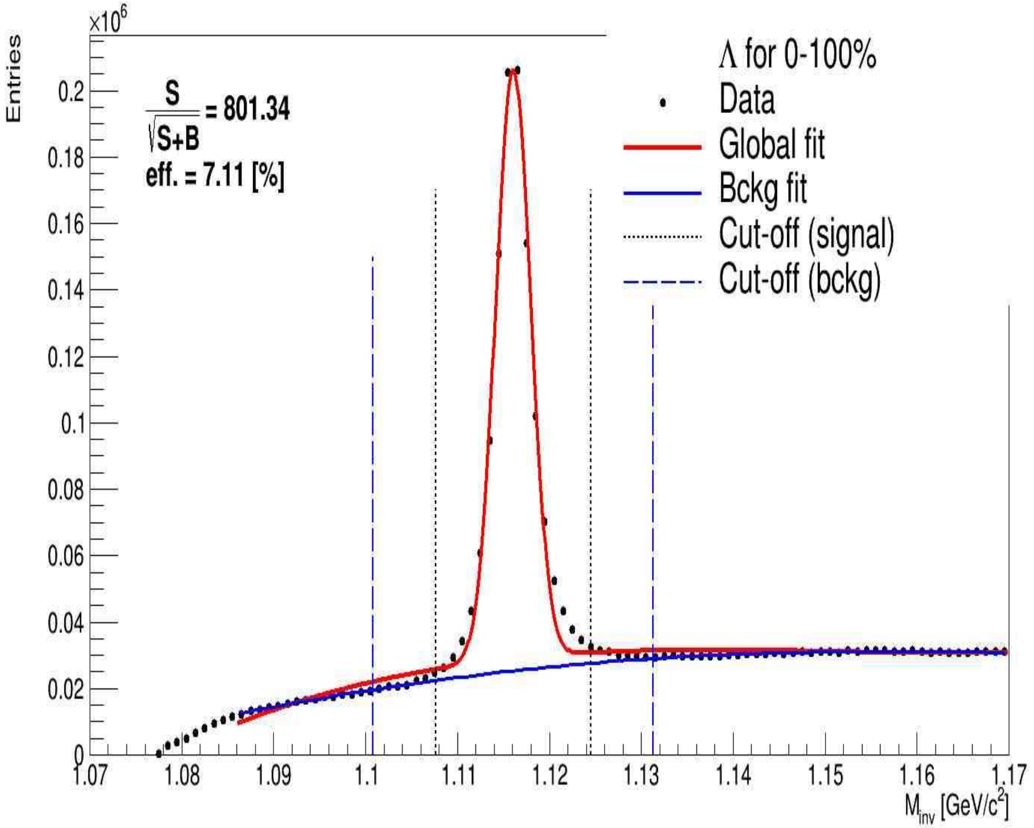
$\bar{\Lambda}$ hyperon

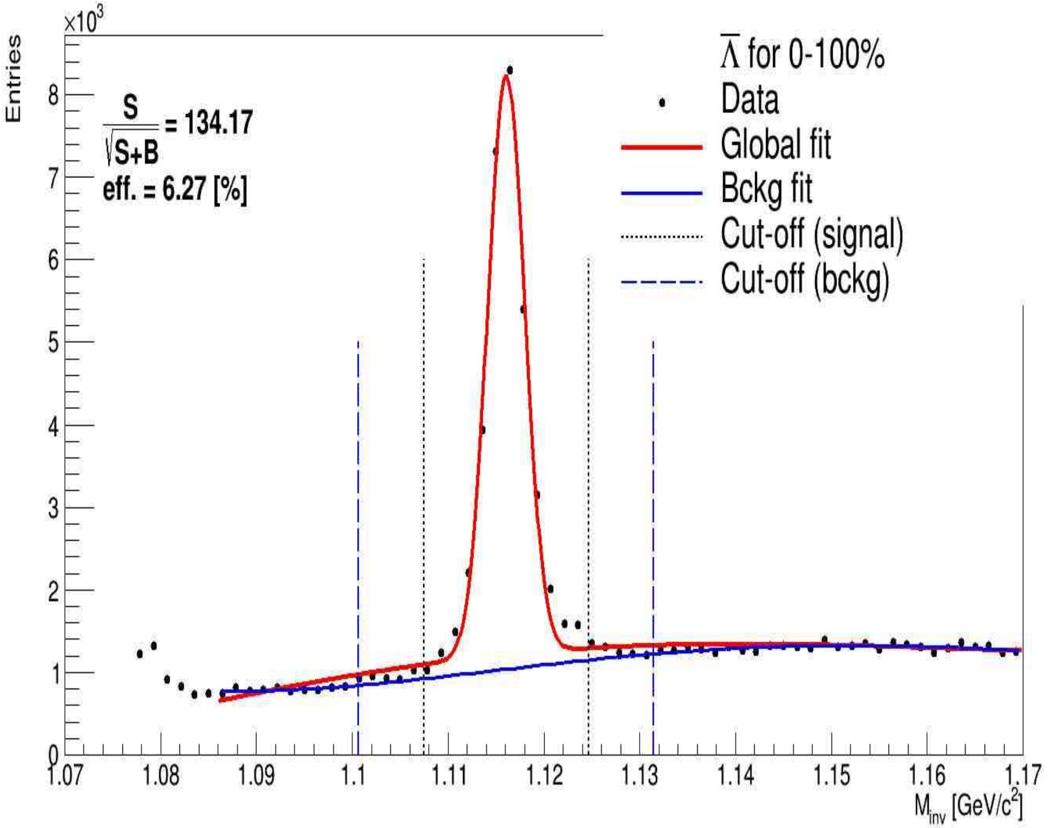
Centrality	Selection cut ϖ_2 at max.sign
0-5%	1.8
5-10%	1.6
10-40%	1.4
40-100%	0.8
0-100%	1.4

Λ hyperons

Centrality	Selection cut ϖ_2 at max.sign
0-5%	2.4
5-10%	2.2
10-40%	1.8
40-100%	1.2
0-100%	2.0

Invariant masses Λ, $\bar{\Lambda}$



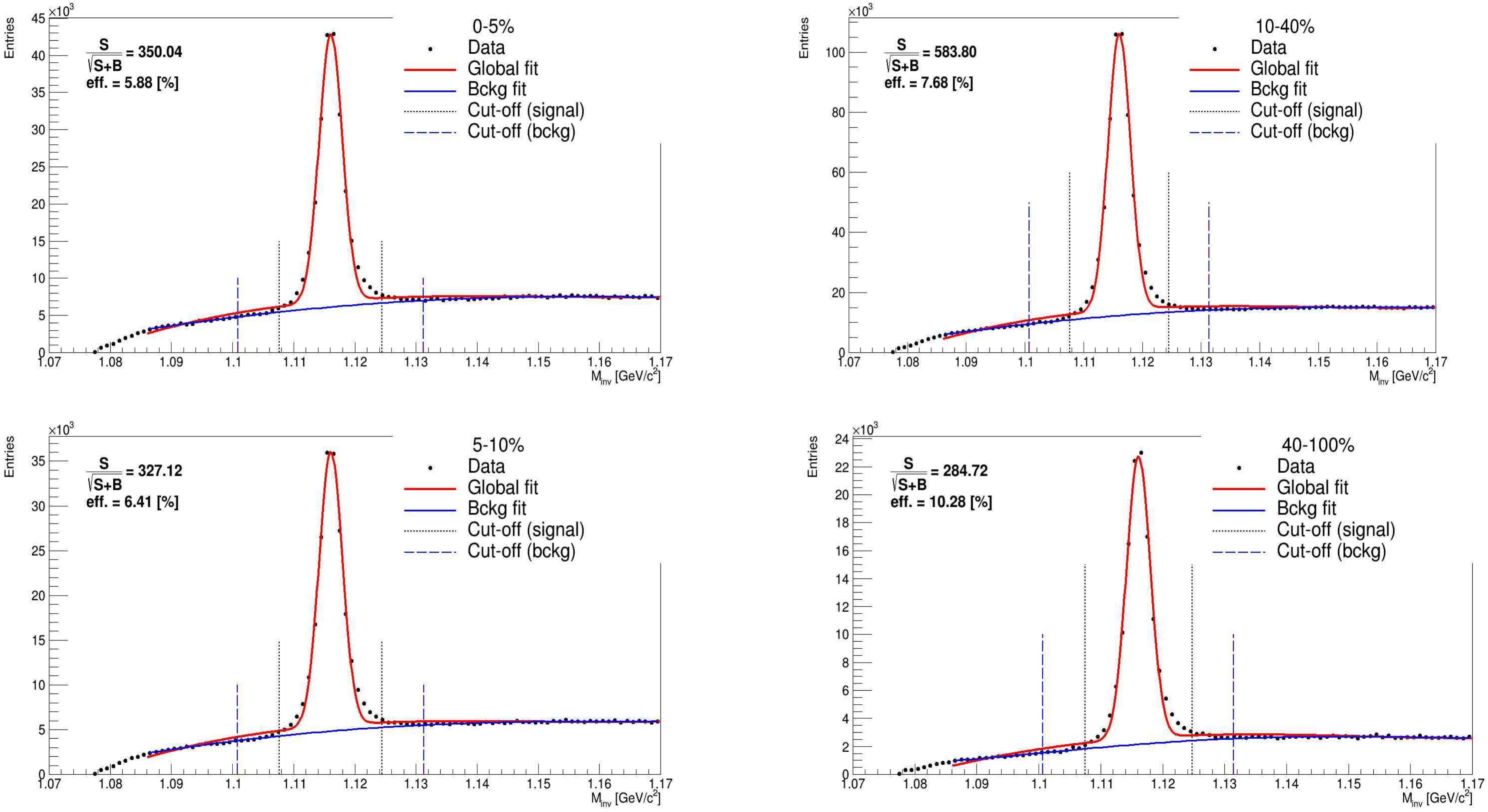


Fitting function:

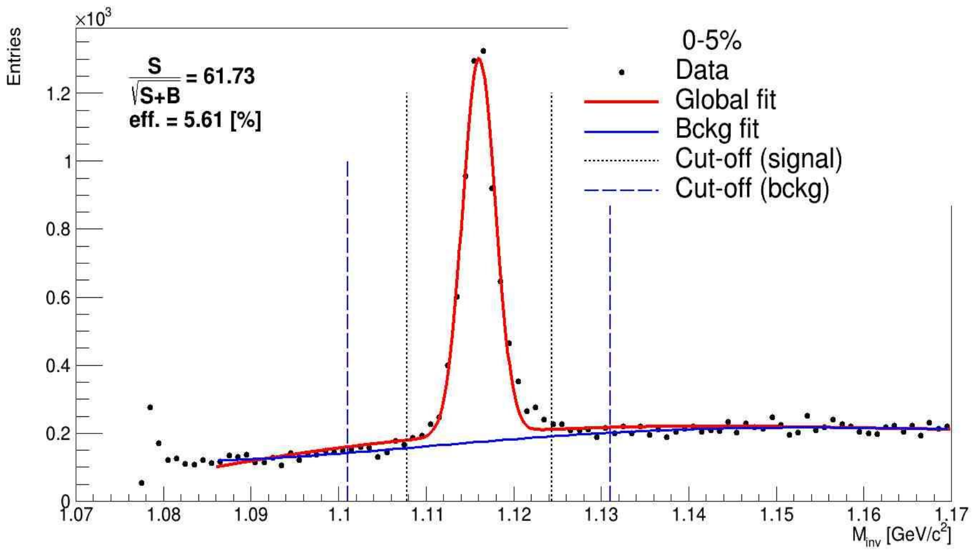
- Legendre polynoms (L_n) for
- background
- Background fit in sidebands
- Cut-off $\langle M_\Lambda \rangle \pm 4\sigma$
- DCA and track-separation cuts

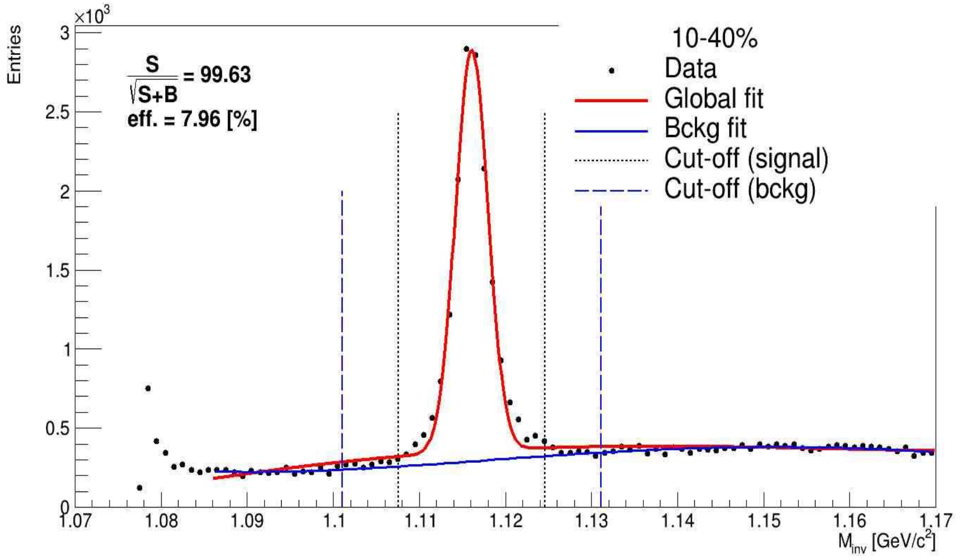
$$f(x) = [0]\exp\left(\frac{(-0.5(x-[1]))^2}{[2]^2}\right) + [3](L_0 + [4]L_1 + [5]L_2 + [6]L_3 + [7]L_4)$$

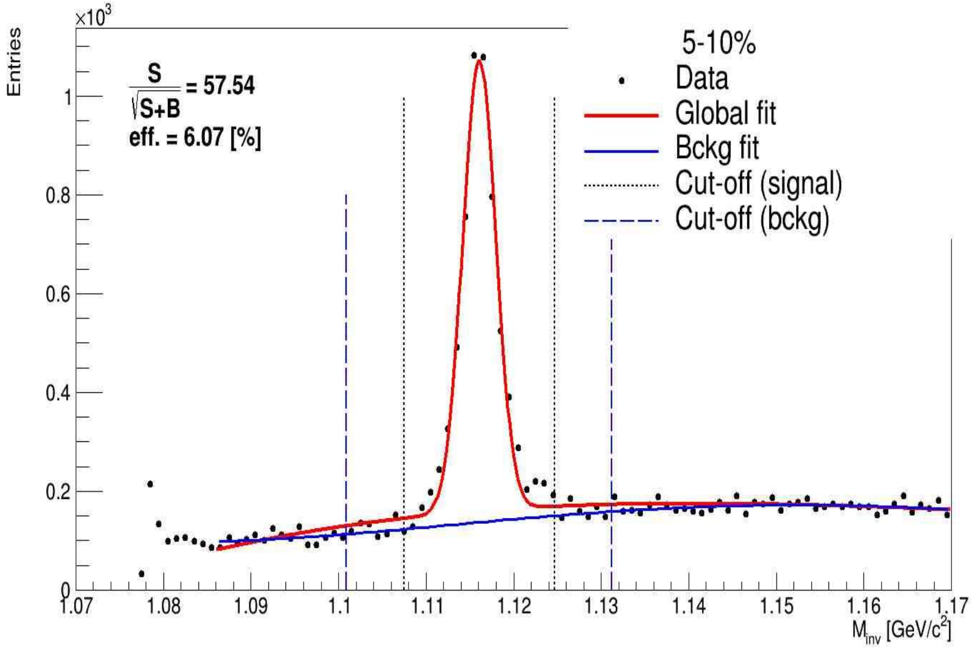
Invariant mass Λ for different centralities

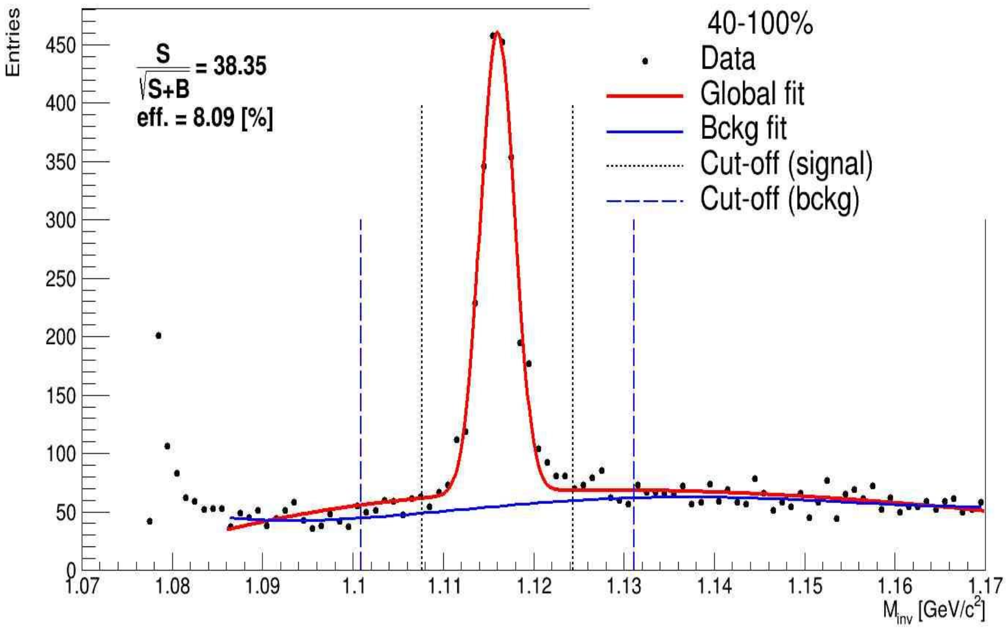


Invariant mass $\bar{\Lambda}$ for different centralities

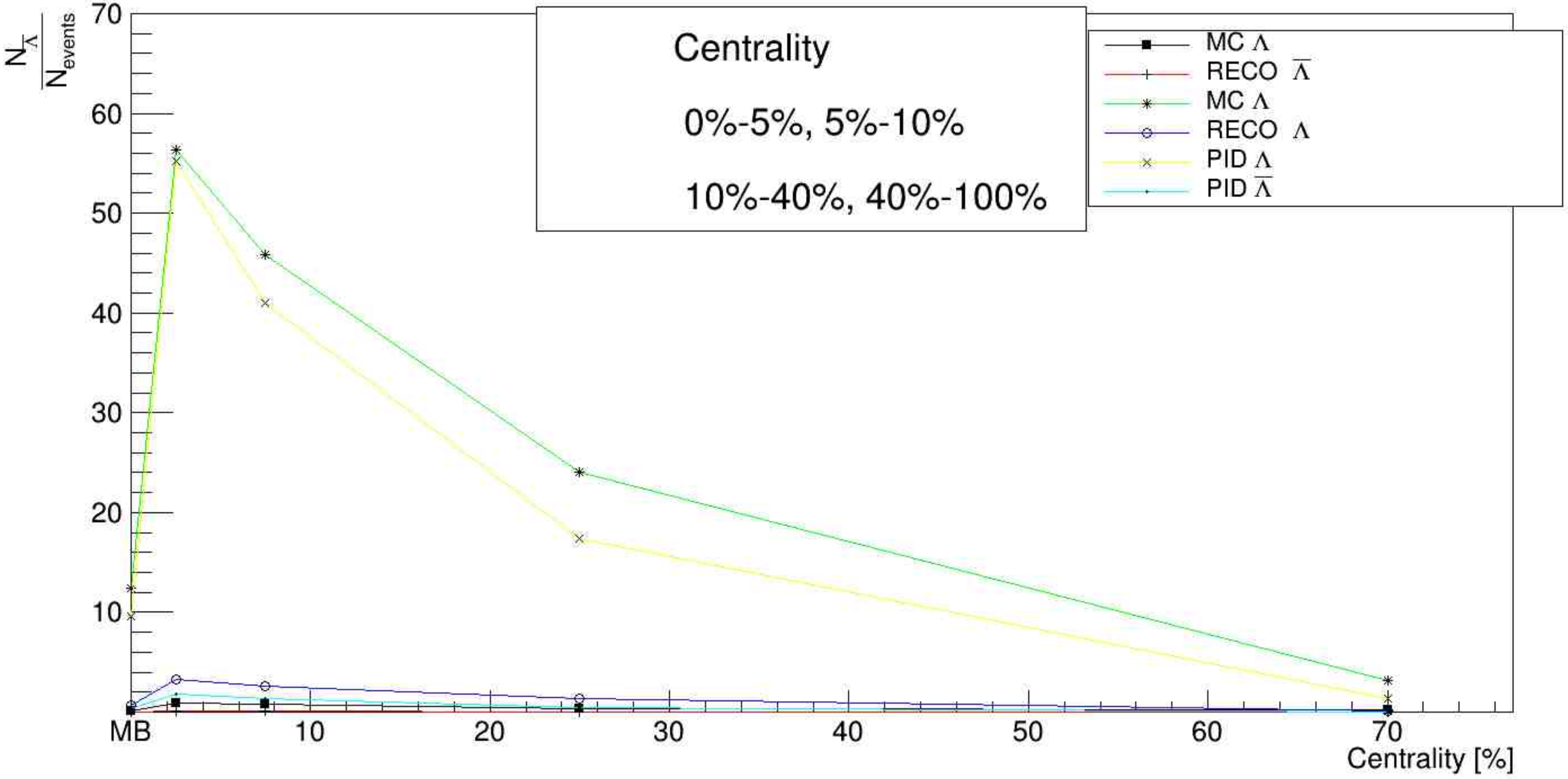




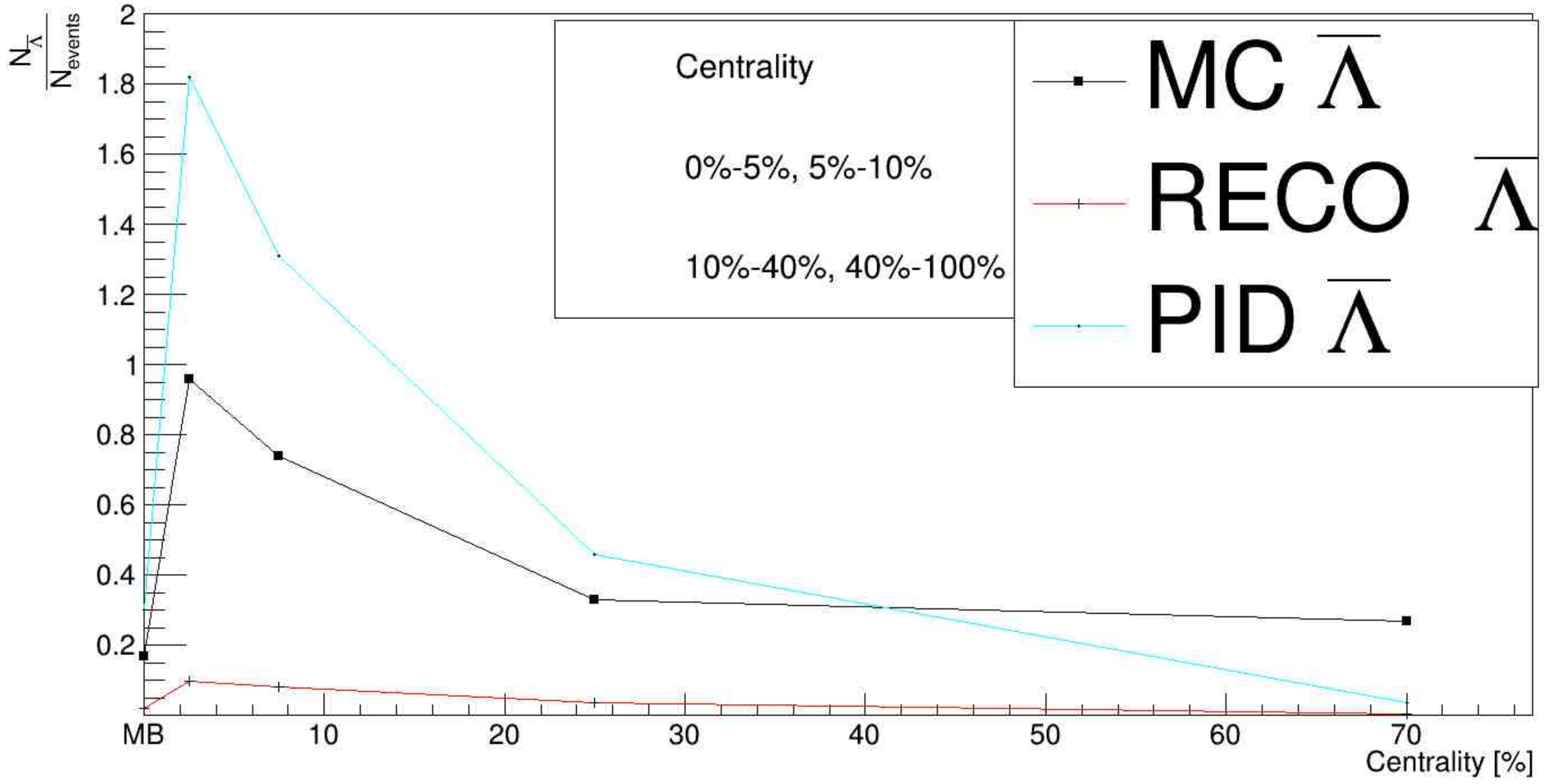




Number of $\bar{\Lambda} - \Lambda$ per event for different centralities



Number of $\bar{\Lambda}$ per event for different centralities



$\bar{\Lambda} - \Lambda$ hyperons yield

MC Λ hyperons

Centrality	Number	Number per events
0-5%	3 338 380	56.32
5-10%	2 851 102	45.82
10-40%	8 845 462	24.03
40-100%	2 306 016	3.121

MC $\bar{\Lambda}$ hyperons

Centrality	Number	Number per events
0-5%	57 334	0.96
5-10%	46 308	0.74
10-40%	123 330	0.33
40-100%	19 935	0.269

PID Λ hyperons

Centrality	Number	Number with selection cut ω_2	Number per events
0-5%	62 107 649	3 273 203	55.2
5-10%	79 497 683	2 550 396	40.98
10-40%	43 758 171	6 421 057	17.4
40-100%	64 718 671	1 065 843	1.4

PID $\bar{\Lambda}$ hyperons

Centrality	Number	Number with selection cut ω_2	Number per events
0-5%	1 367 159	108 132	1.82
5-10%	8 823 384	81 623	1.31
10-40%	1 454 977	172 069	0.46
40-100%	87 294	26 507	0.035

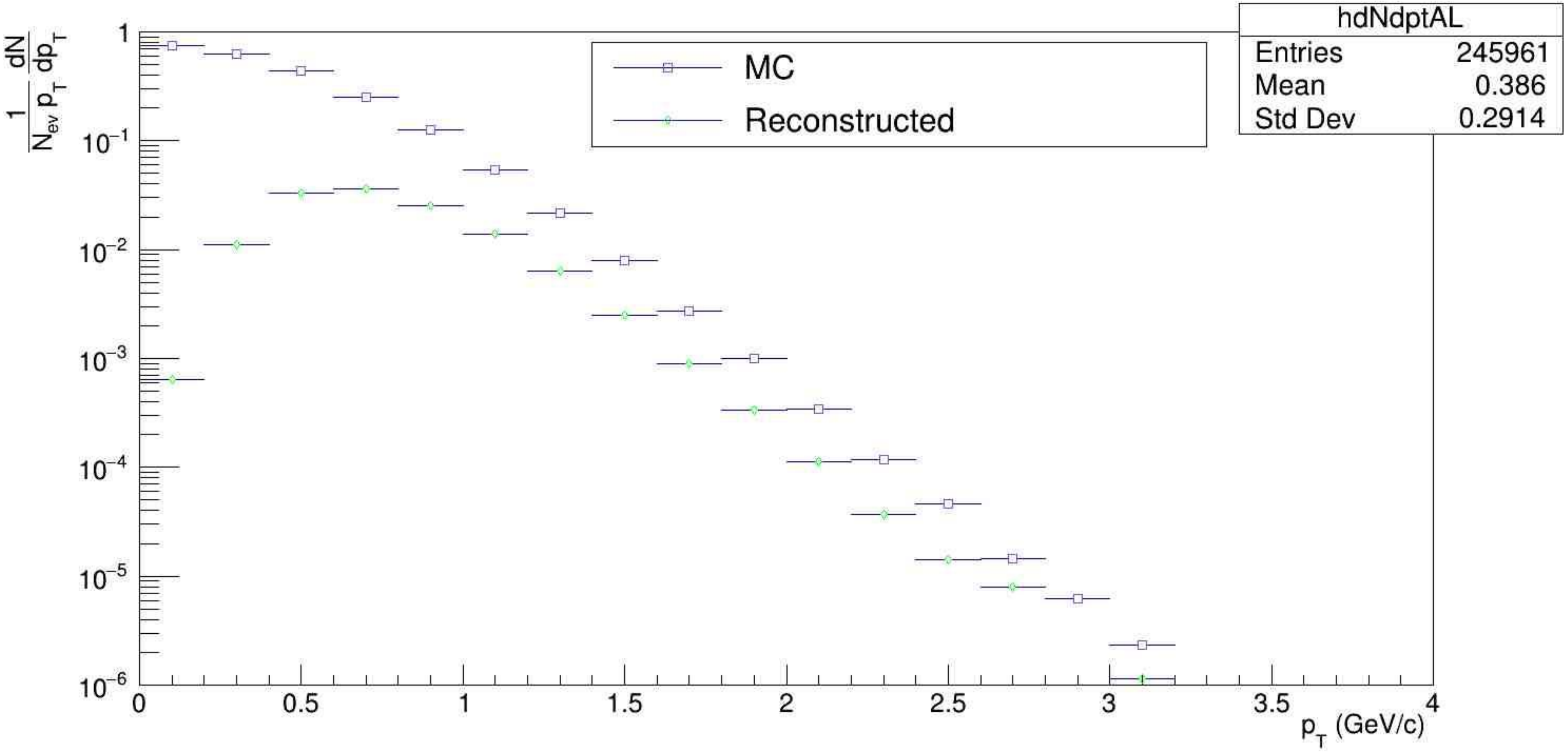
Reconstructed Λ hyperons

Centrality	Number	Number per events
0-5%	191 649	3.23
5-10%	162 863	2.617
10-40%	491 715	1.33
40-100%	109 312	0.14

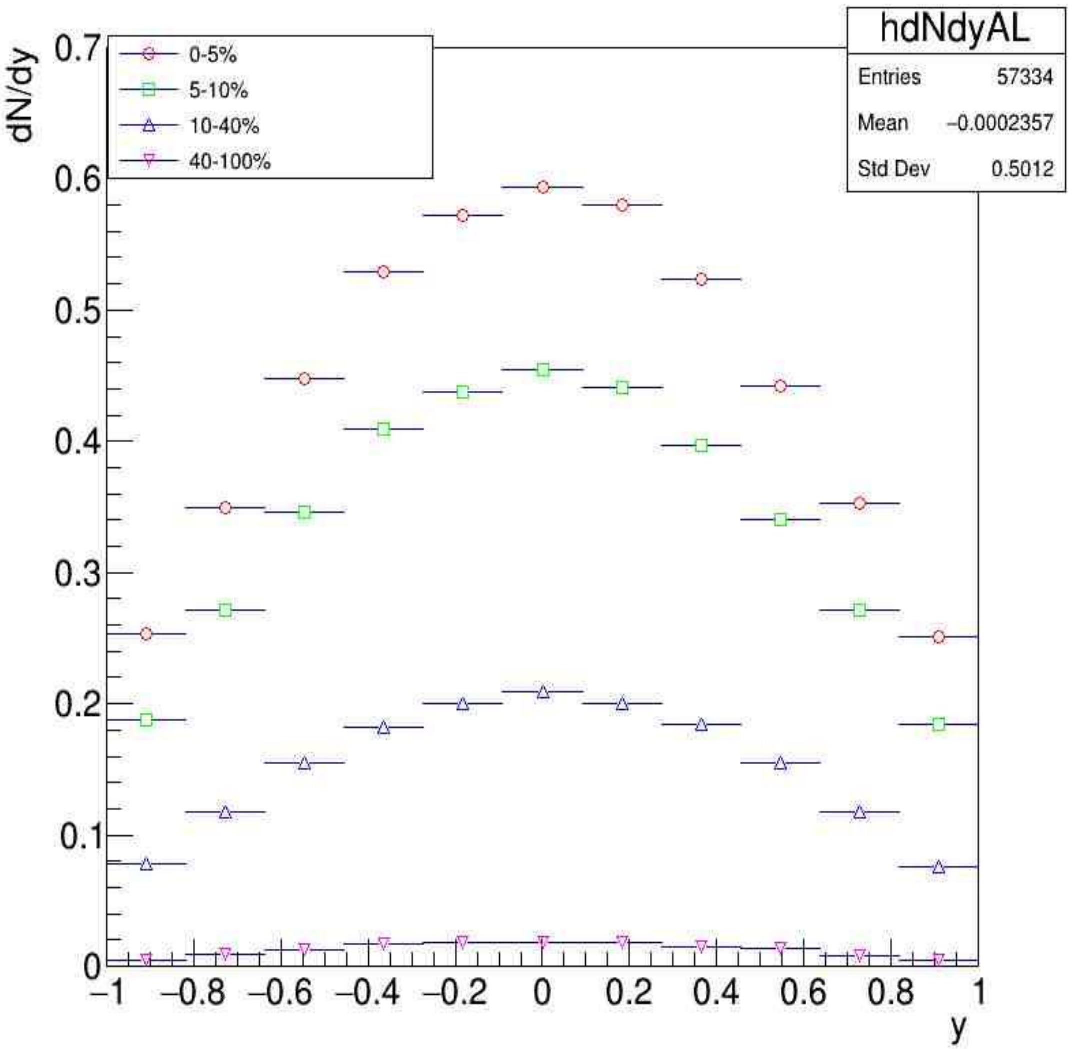
Reconstructed $\bar{\Lambda}$ hyperons

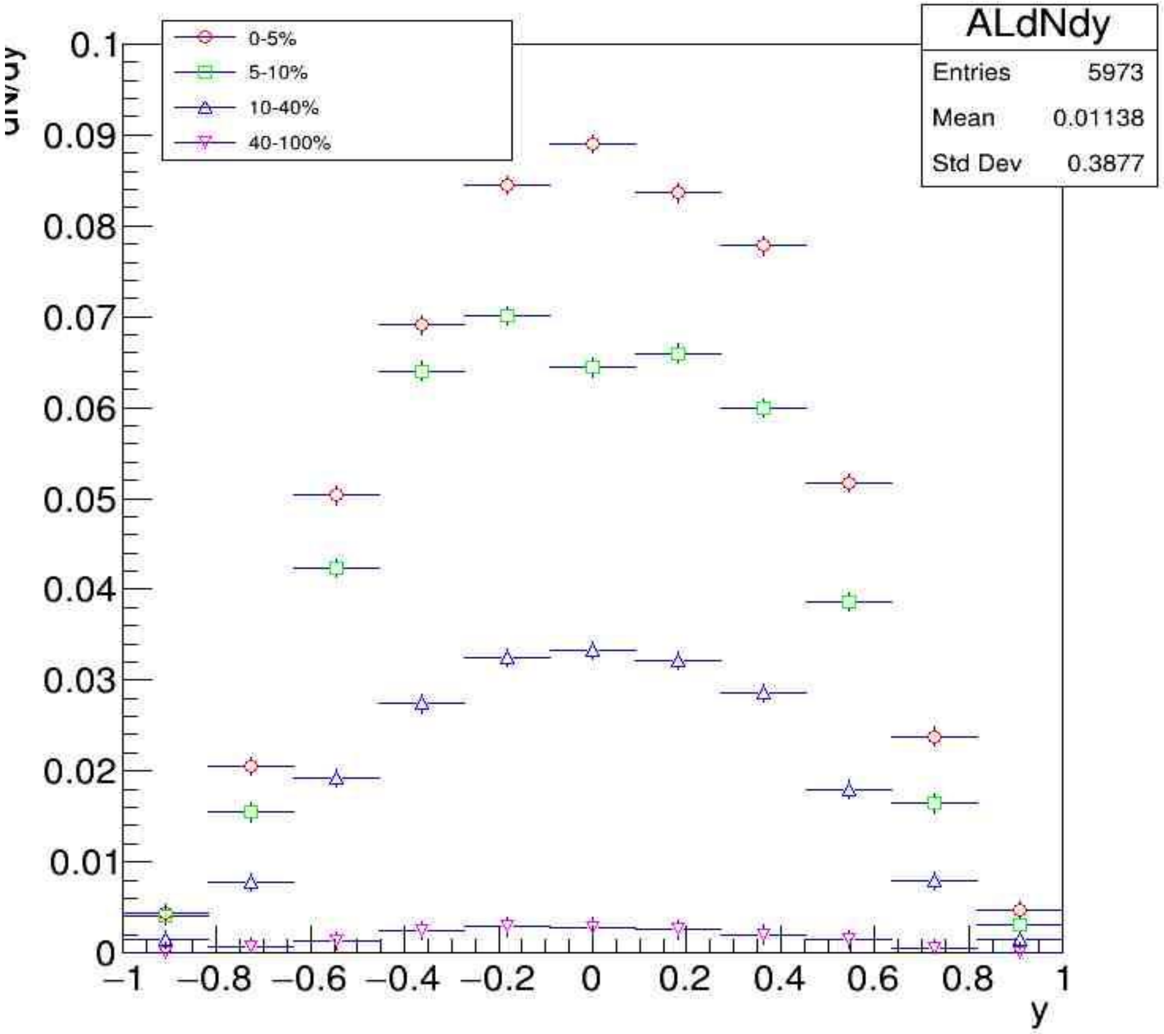
Centrality	Number	Number per events
0-5%	5861	0.098
5-10%	5000	0.08
10-40%	13698	0.037
40-100%	2132	0.0028

$\overline{\Lambda}$ hyperon yield vs p_T



$\bar{\Lambda}$ hyperon yield vs rapidity





Factors affecting $\bar{\Lambda}$ reconstruction efficiency.

0-5 % centrality

Factor	Efficiency, %
Branching ratio: $\bar{\Lambda} \rightarrow \bar{p} + \pi^+$	61.9
$\bar{p}$ and π^+at $\|\eta\|$<1.3	35.6
$\bar{p}$ and π^+at $\|\eta\|$<1.3 and p_T>0.05 GeV/c	33.2
$\bar{p}$ and π^+at $\|\eta\|$<1.3 and p_T>0.1 GeV/c	24.4
$\bar{p}$ and π^+at $\|\eta\|$<1.3 and p_T>0.2 GeV/c	7.3
Reconstructed $\bar{p}$ and π^+at $\|\eta\|$<1.3	22.7
Maximum significance	10.4

10-40 % centrality

Factor	Efficiency, %
Branching ratio: $\bar{\Lambda} \rightarrow \bar{p} + \pi^+$	62
$\bar{p}$ and π^+at $\|\eta\|$<1.3	35.8
$\bar{p}$ and π^+at $\|\eta\|$<1.3 and p_T>0.05 GeV/c	33.3
$\bar{p}$ and π^+at $\|\eta\|$<1.3 and p_T>0.1 GeV/c	24.4
$\bar{p}$ and π^+at $\|\eta\|$<1.3 and p_T>0.2 GeV/c	7.1
Reconstructed $\bar{p}$ and π^+at $\|\eta\|$<1.3	23.1
Maximum significance	11.4

5-10 % centrality

Factor	Efficiency, %
Branching ratio: $\bar{\Lambda} \rightarrow \bar{p} + \pi^+$	62
$\bar{p}$ and π^+at $\|\eta\|$<1.3	35.7
$\bar{p}$ and π^+at $\|\eta\|$<1.3 and p_T>0.05 GeV/c	33.2
$\bar{p}$ and π^+at $\|\eta\|$<1.3 and p_T>0.1 GeV/c	24.7
$\bar{p}$ and π^+at $\|\eta\|$<1.3 and p_T>0.2 GeV/c	7.3
Reconstructed $\bar{p}$ and π^+at $\|\eta\|$<1.3	22.9
Maximum significance	11

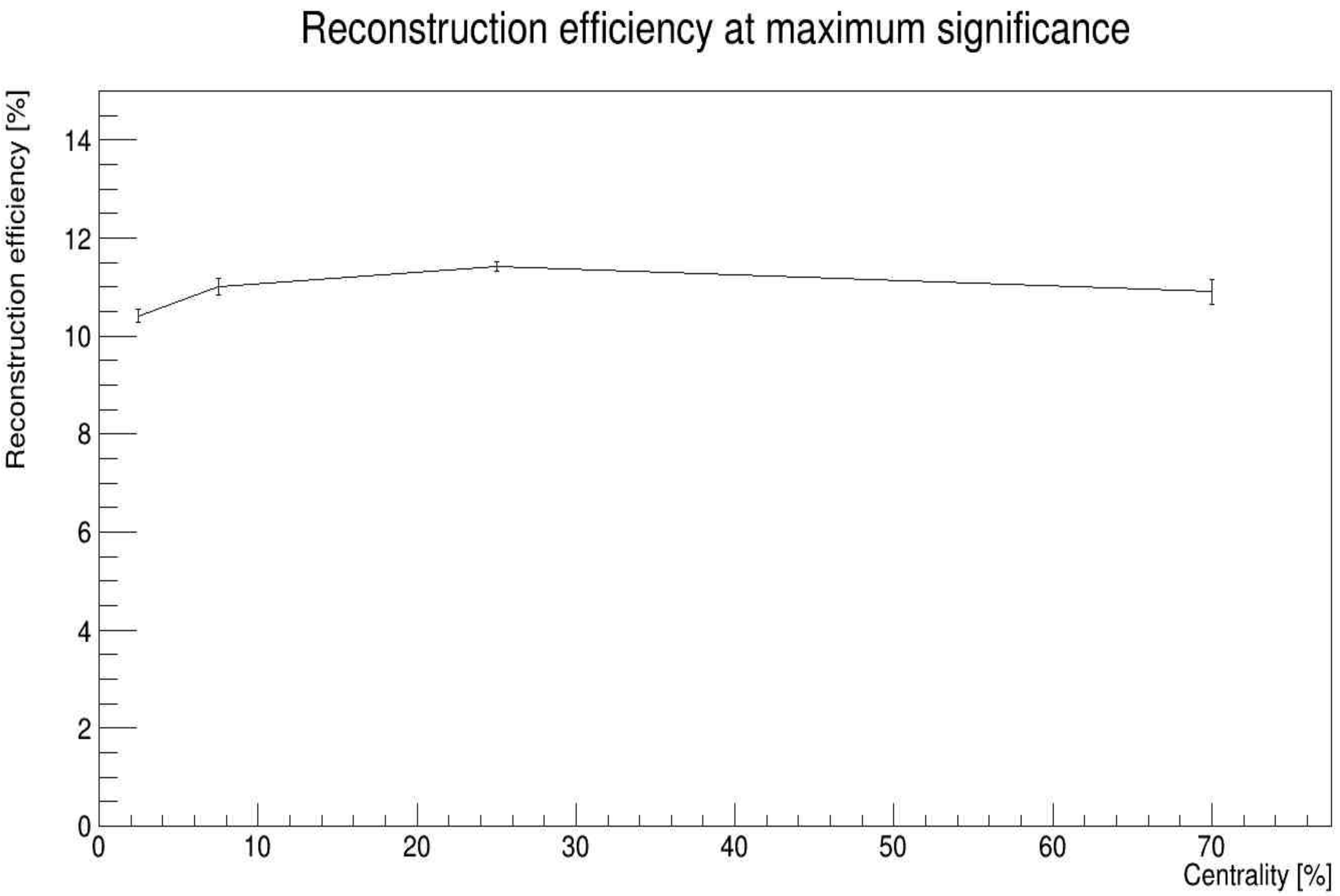
40-100 % centrality

Factor	Efficiency, %
Branching ratio: $\bar{\Lambda} \rightarrow \bar{p} + \pi^+$	62.2
$\bar{p}$ and π^+at $\|\eta\|$<1.3	36.3
$\bar{p}$ and π^+at $\|\eta\|$<1.3 and p_T>0.05 GeV/c	33.6
$\bar{p}$ and π^+at $\|\eta\|$<1.3 and p_T>0.1 GeV/c	23.3
$\bar{p}$ and π^+at $\|\eta\|$<1.3 and p_T>0.2 GeV/c	5.8
Reconstructed $\bar{p}$ and π^+at $\|\eta\|$<1.3	22.2
Maximum significance	10.9

Factors affecting $\overline{\Lambda}$ reconstruction efficiency.

0-100 % centrality

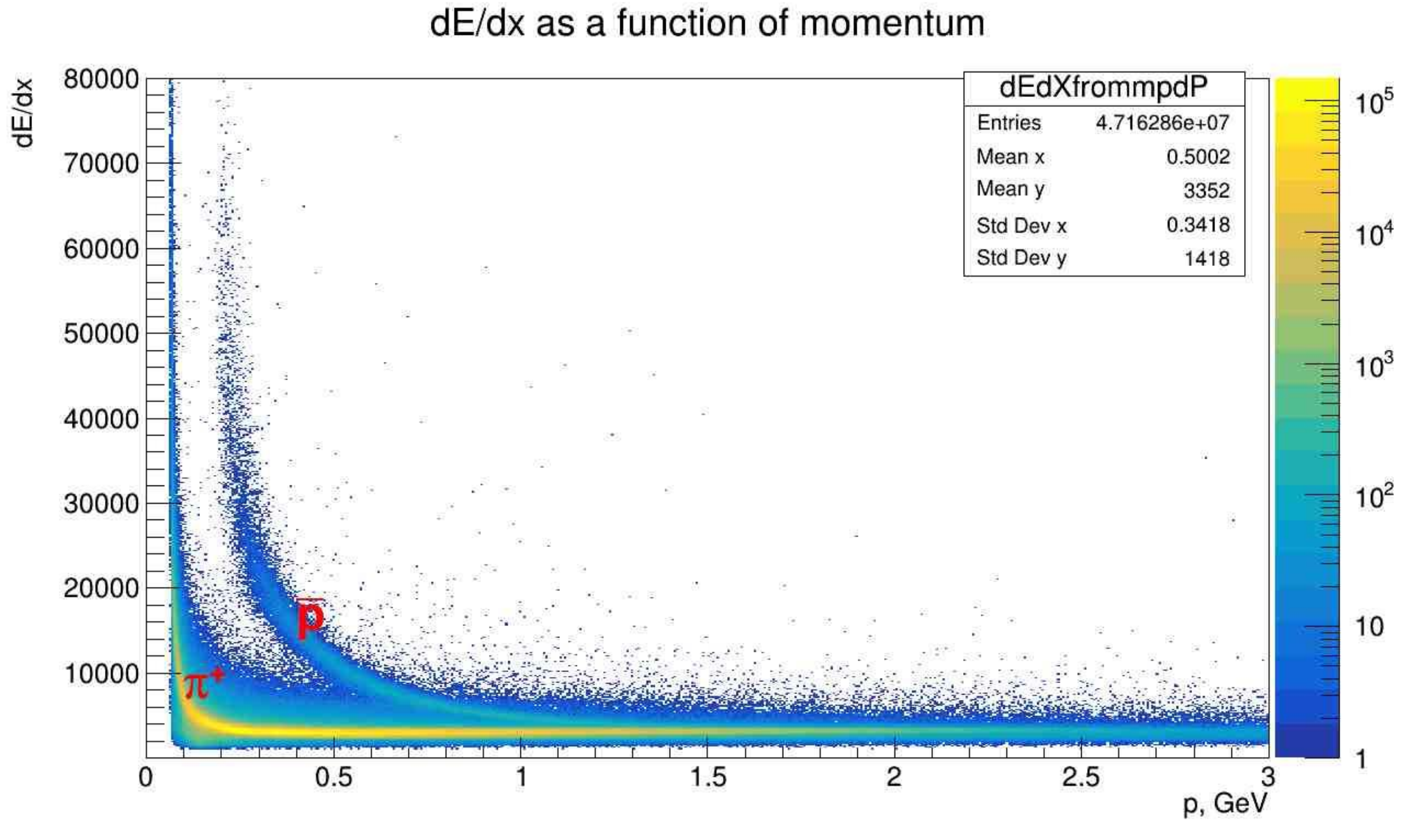
Factor	Efficiency, %
Branching ratio: $\overline{\Lambda} \rightarrow \bar{p} + \pi^+$	62
$\bar{p}$ and π^+at $\lvert\eta\rvert$<1.3	35.8
$\bar{p}$ and π^+at $\lvert\eta\rvert$<1.3 and p_T>0.05 GeV/c	33.3
$\bar{p}$ and π^+at $\lvert\eta\rvert$<1.3 and p_T>0.1 GeV/c	24.3
$\bar{p}$ and π^+at $\lvert\eta\rvert$<1.3 and p_T>0.2 GeV/c	7
Reconstructed $\bar{p}$ and π^+at $\lvert\eta\rvert$<1.3	22.9
Maximum significance	11.2

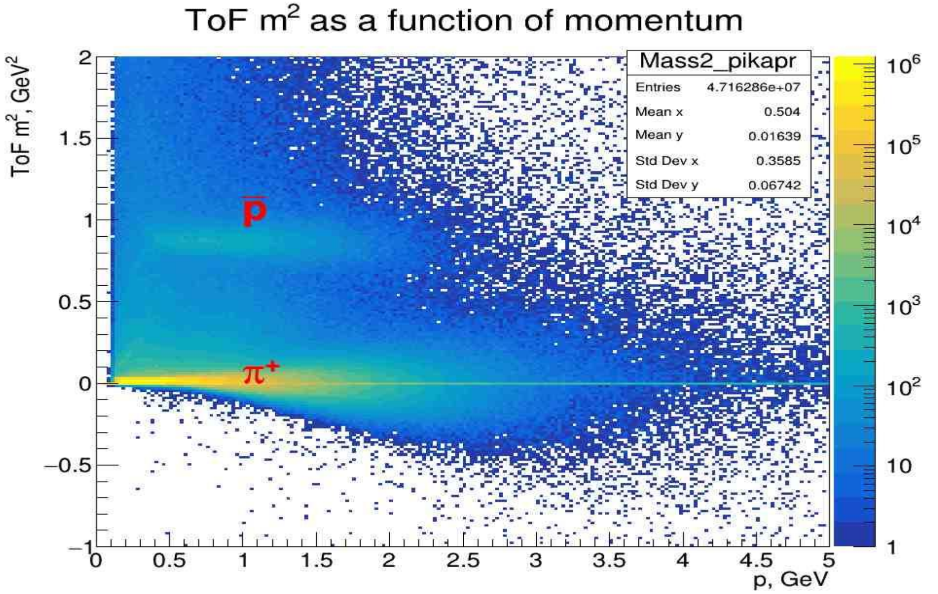

Reconstruction efficiency at maximum significance
Reconstruction efficiency [%]
0
2
4
6
8
10
12
14
0
10
20
30
40
50
60
70
Centrality [%]

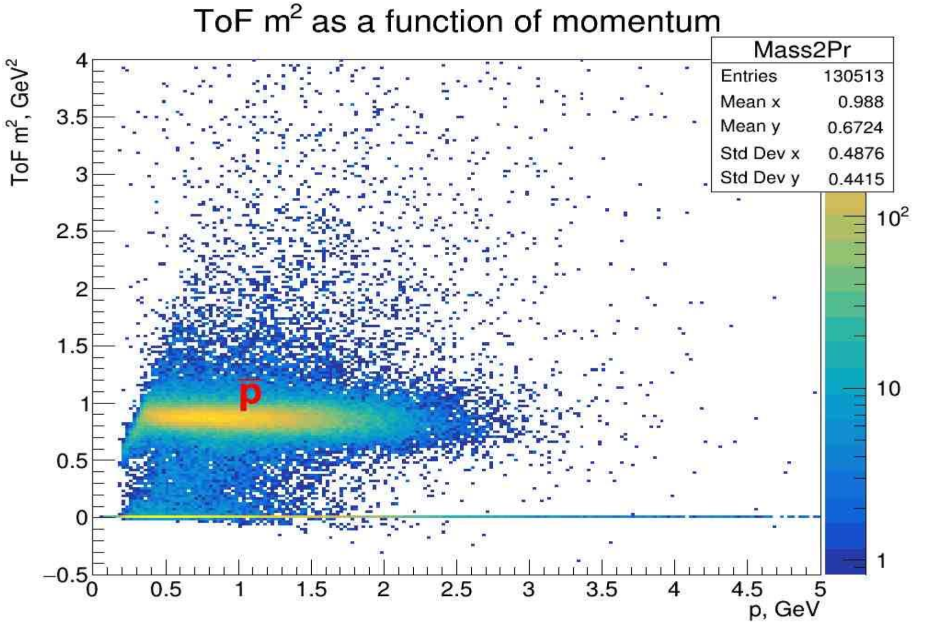
MPD PID for the analysis

$$\Lambda \to p + \pi^-$$

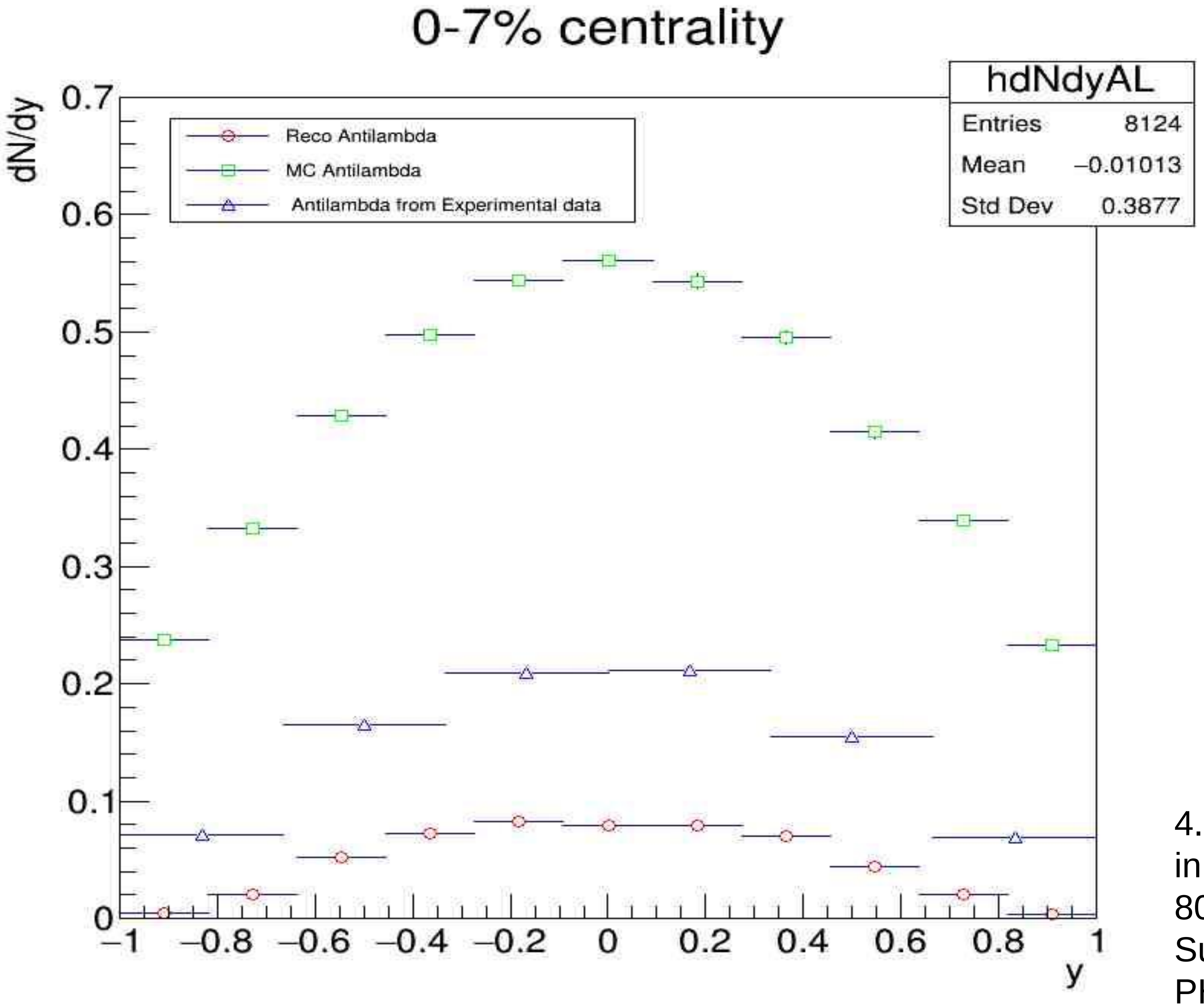
$$\bar{\Lambda} \to \bar{p} + \pi^+$$







Comparison with experimental data



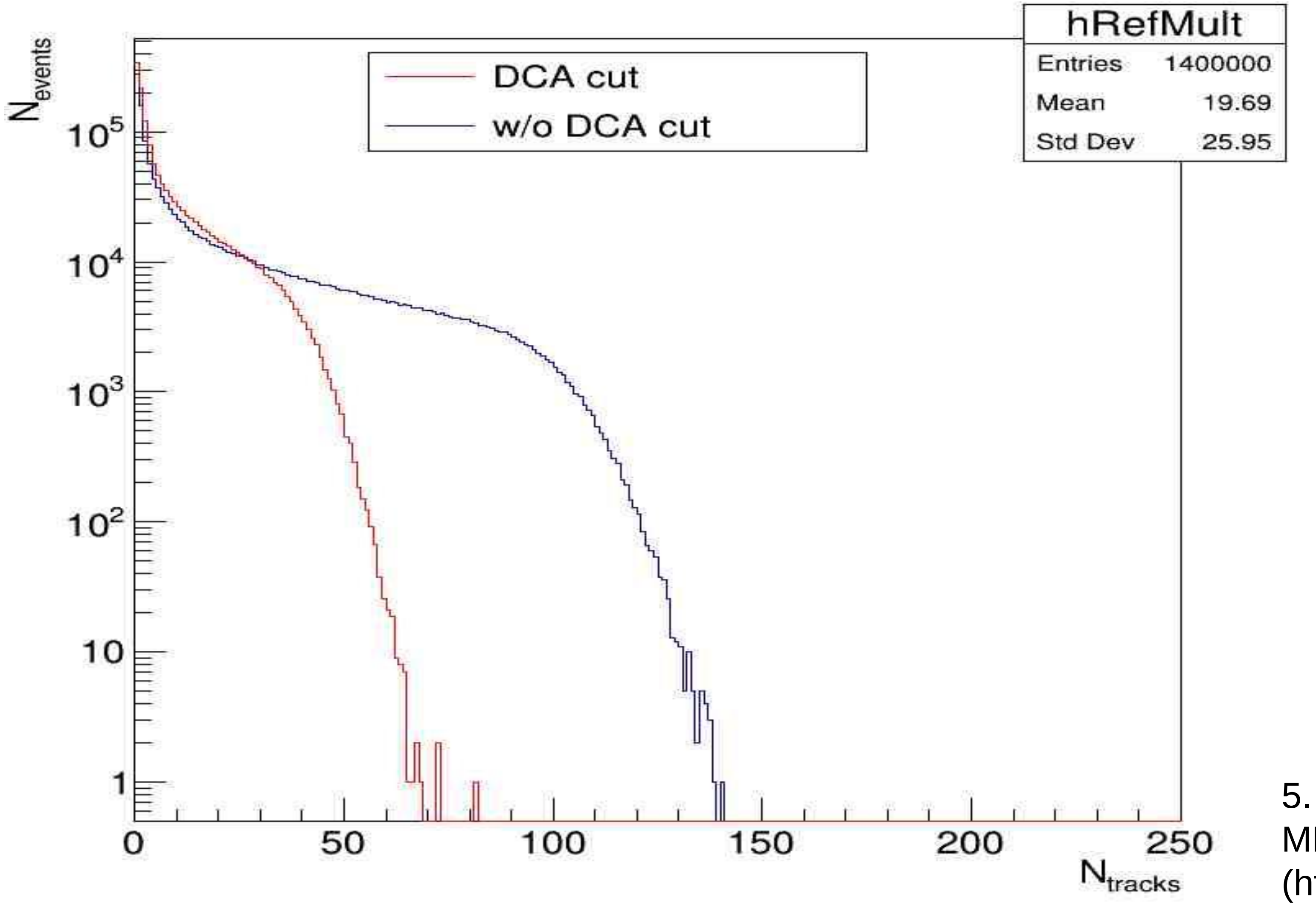
Experimental data[4]:

- PbPb collision at 7.6 GeV
- 420 K events
- 0-7% centrality fraction

4. Energy dependence of Λ and Ξ production in central Pb+Pb collisions at 20A, 30A, 40A, 80A, and 158A GeV measured at the CERN Super Proton Synchrotron
PHYSICAL REVIEW C 78, 034918 (2008)

Centrality determination (Multiplicity in TPC)

- MC-Glauber based centrality framework[5]



Cuts:

$p_T > 0.15$ GeV/c

$|\eta| < 0.5$

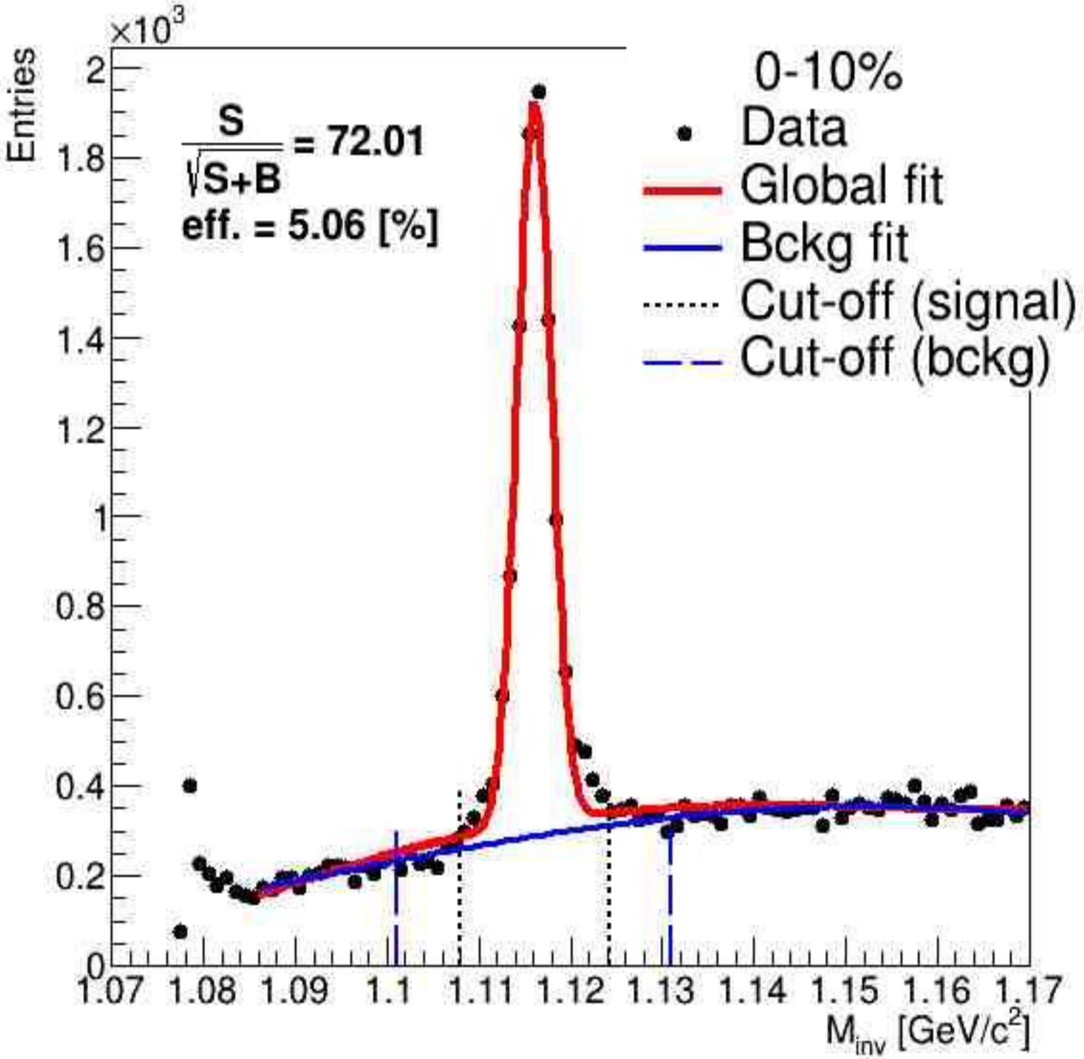
$N_{hits} > 16$

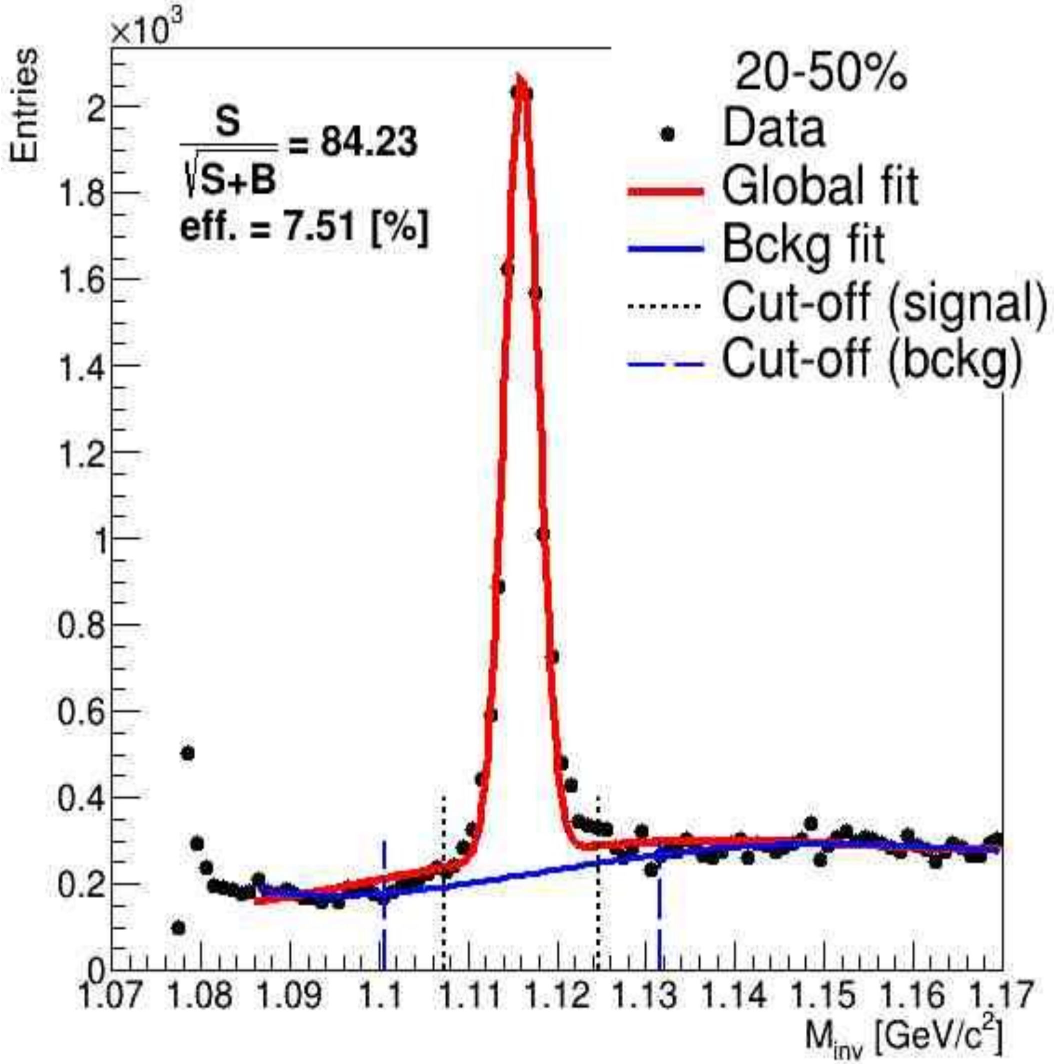
$|DCA| < 0.5$ cm

w/o DCA cut is used for analysis

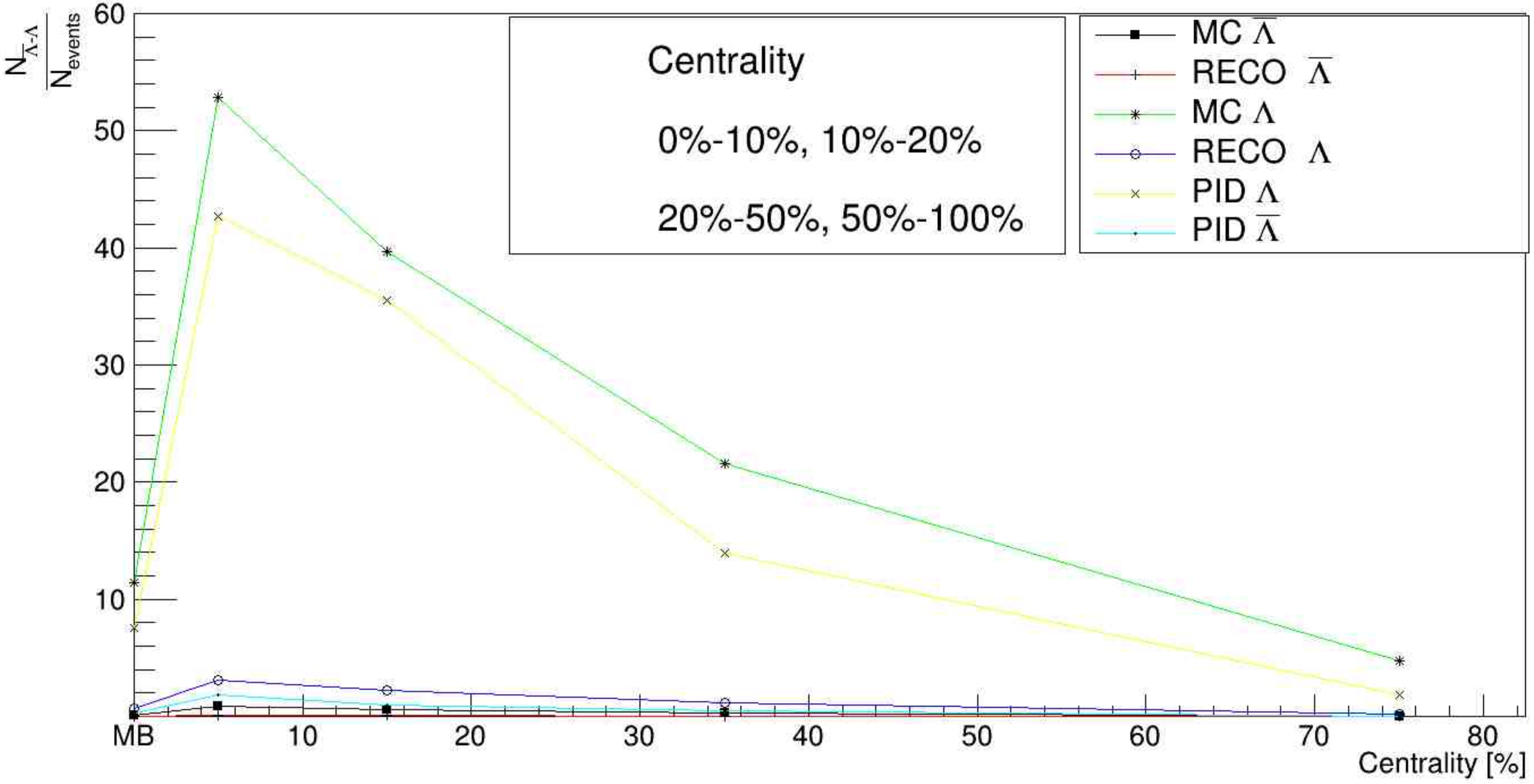
5. P. Parfenov et al, NRNU MEPhI for the MPD collaboration (https://github.com/FlowNICA/CentralityFramework)

Invariant masses $\bar{\Lambda}$

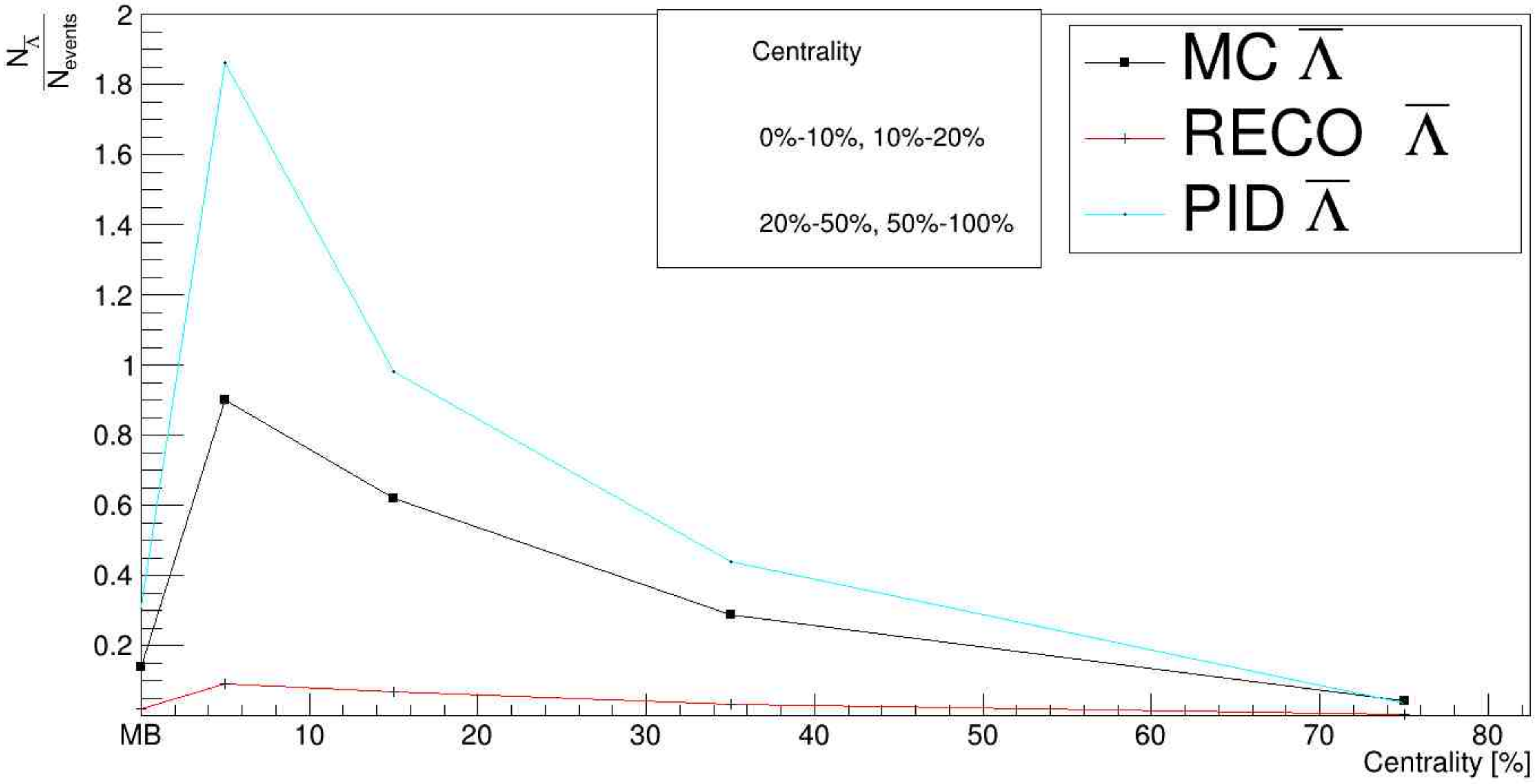




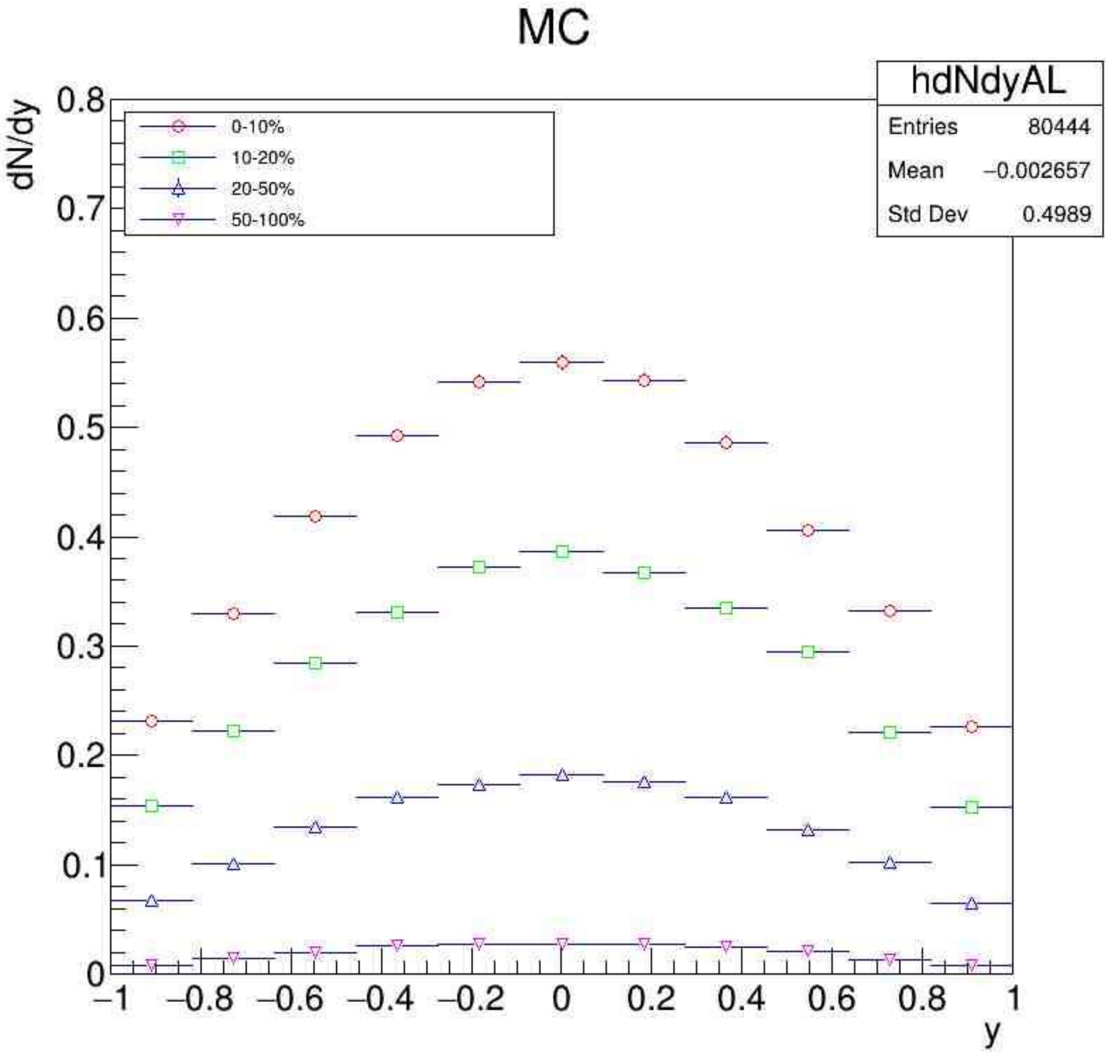
Number of $\bar{\Lambda} - \Lambda$ per event for different centralities (new determination of centrality)

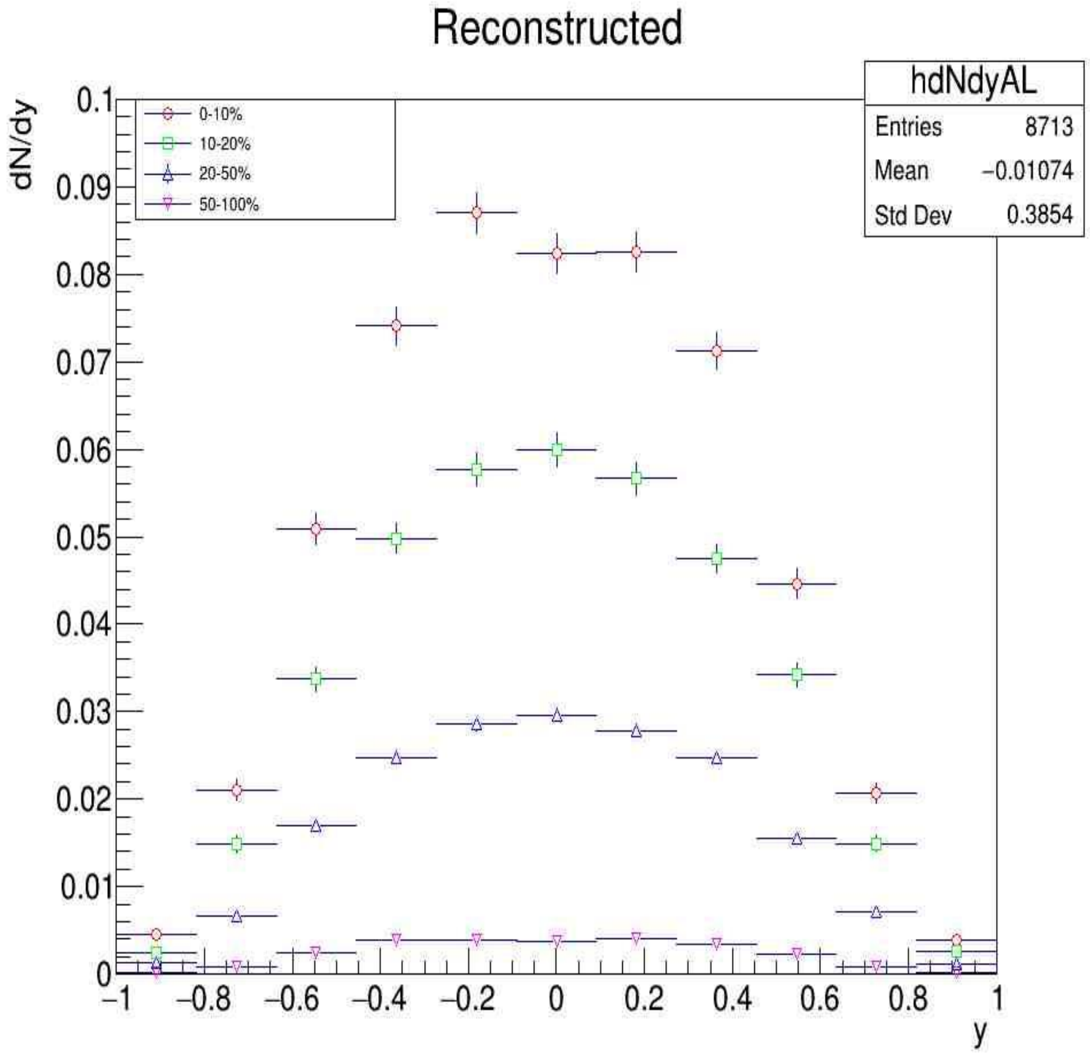


Number of $\bar{\Lambda}$ per event for different centralities

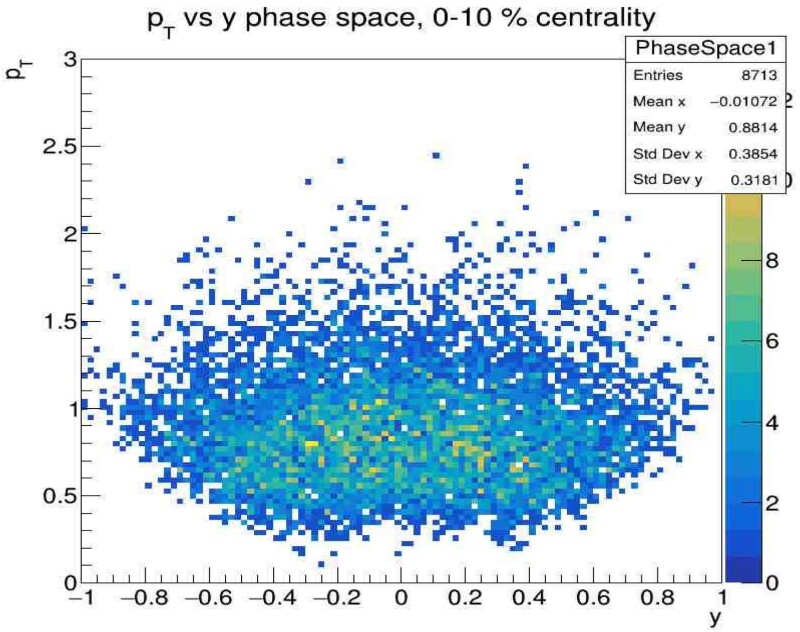


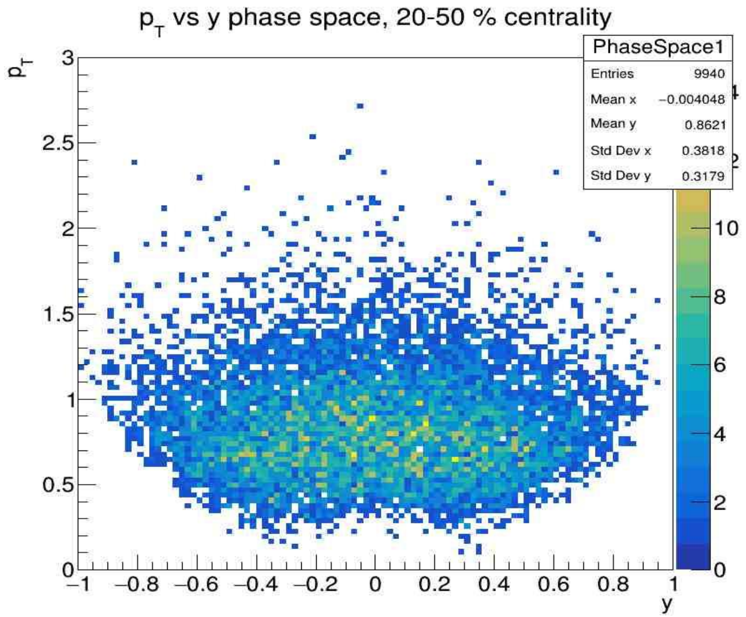
$\bar{\Lambda}$ hyperon yield vs rapidity

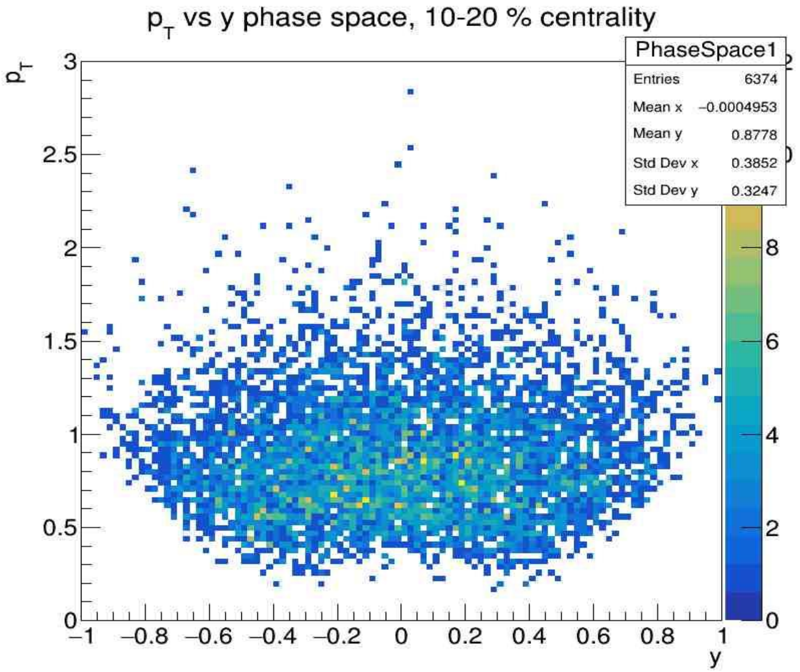


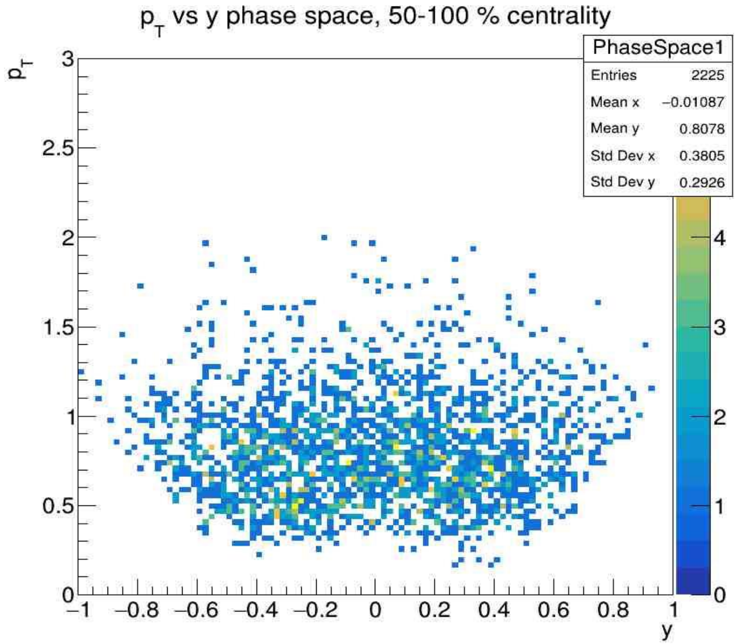


Phase space for $\bar{\Lambda}$ hyperon (selected true)

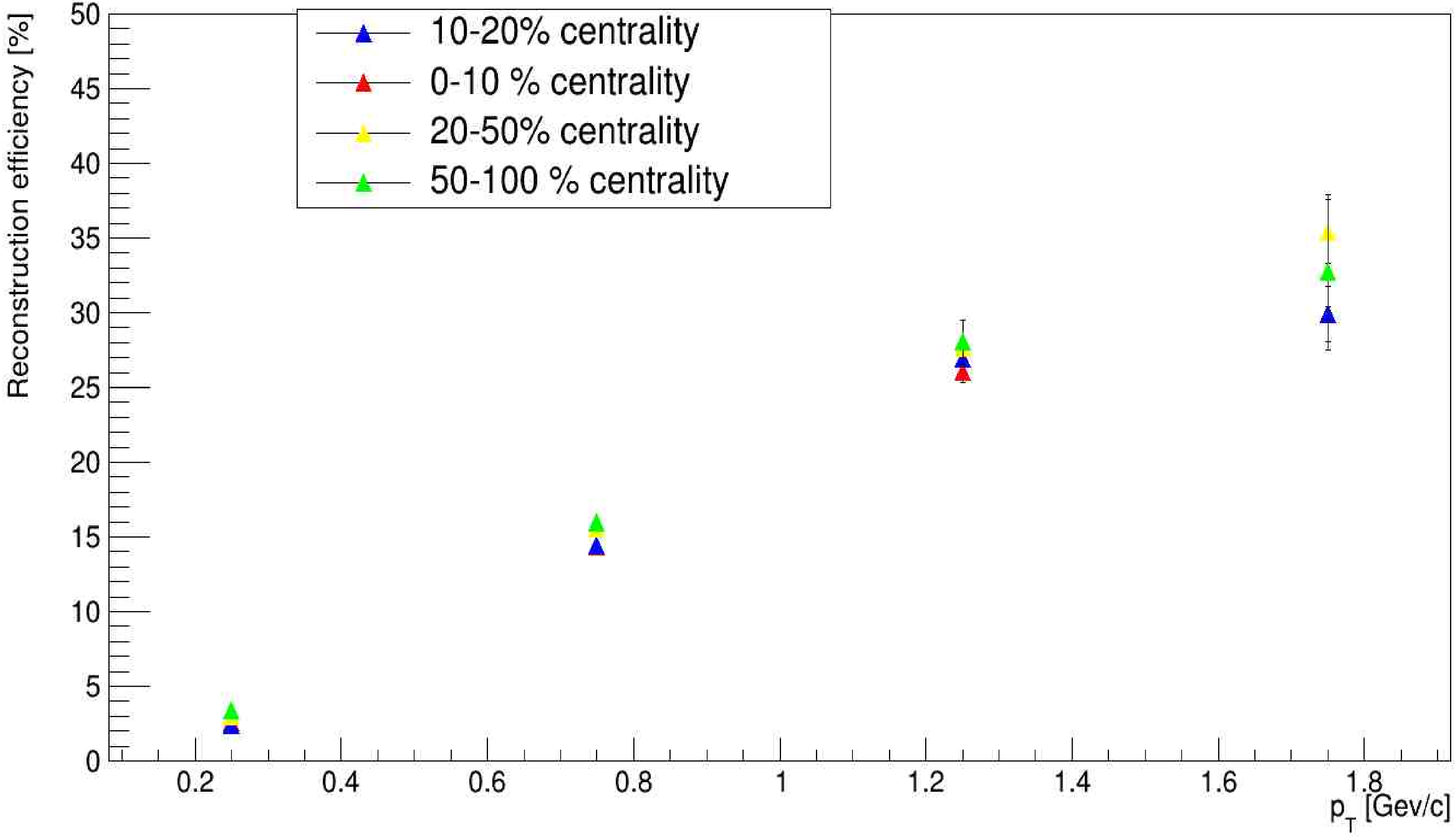








Reconstruction efficiency for $\bar{\Lambda}$ hyperon



Conclusion

- $\overline{\Lambda}$ and Λ reconstruction efficiency was studied in terms of impact parameter
- Implemented MC-Glauber framework for centrality determination
- Differential analysis will require larger statistics
- (ongoing) $\overline{\Lambda}$ reconstruction efficiency in terms of new definition of centrality

Thank you for your attention