LCG Physics Validation meeting, CERN, 28 February 2007

3rd simple benchmark:

Geant4 and Fluka validation

on inclusive $\pi^{\pm}$ production in $\pi^{\pm}$, K^{+}, p, $\underline{p}$
interactions on ***Mg***, ***Ag***, ***Au***,
at **100** and **320** (π^{-}) ***GeV/c***

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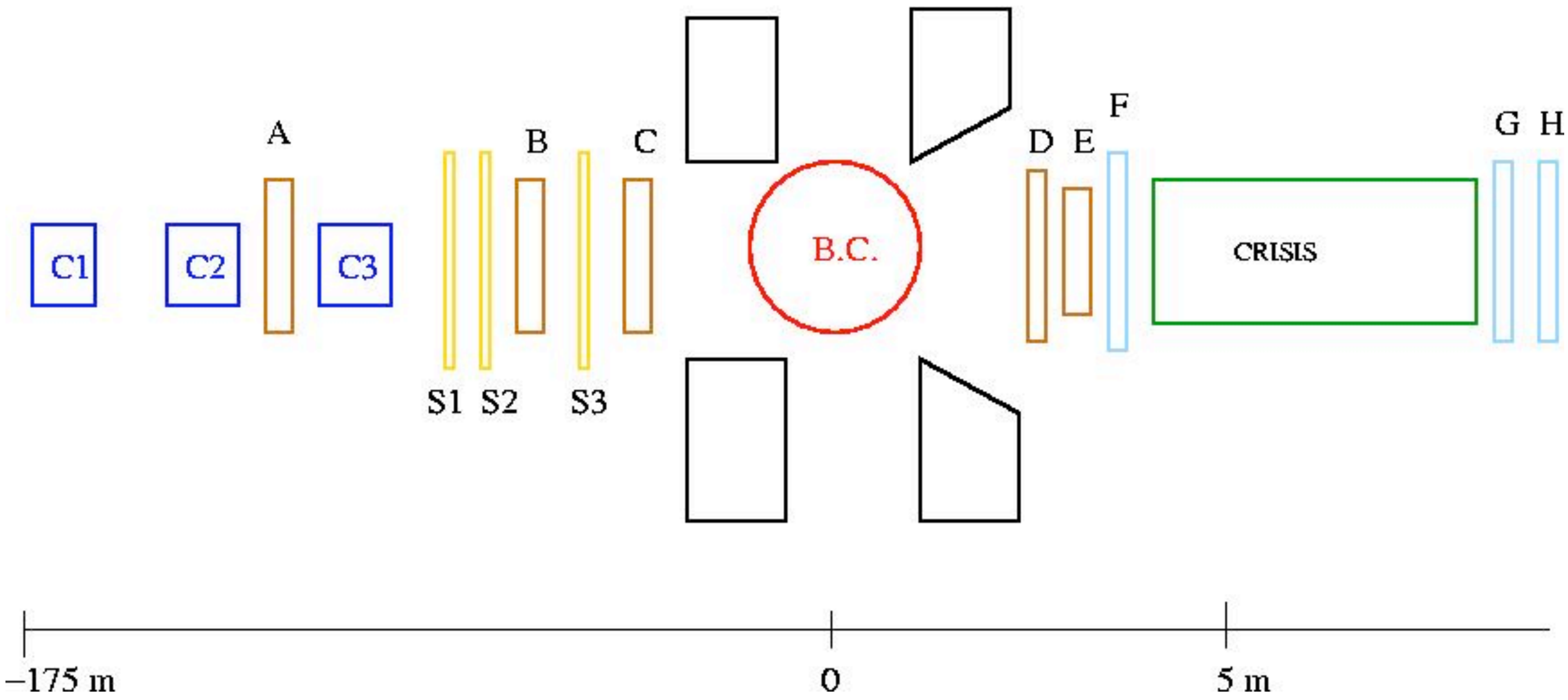
Outline

- Description of the setup
- Simulation and analysis
- Results

3rd simple benchmark:

"Inclusive charged pion production in hadron-nucleus interactions on at 100 and 320 *GeV/c*"

J.J.Whitmore et al, Z.Phys.C62 (1994) 199.



Description of the experiment

- Fermilab experiment E597 (1981-82).
  Fermilab 30-inch bubble chamber spectrometer with the associated Downstream Particle Identifier (DPI).

- **C1**, **C2**, **C3** : Cherenkov counters for identification of beam particles (C1 and C3 contain helium; C2 contains nitrogen).
- **S1**, **S2**, **S3** : scintillators for the DPI trigger.
- **B.C.** : Bubble Chamber in a **2T** magnetic field, filled with liquidH_2 , containing 6 thin foils of Mg, Ag, and Au.
- **A**, **B**, **C**, **D**, **E** : proportional wire chambers, for tracking.
- **F**, **G**, **H** : drift chambers, for tracking.
- **CRISIS** : (Considerably Reduced ISIS (Identification of Secondaries by Ionization Sampling)) a 1m x 1m x 3m ionization sampling drift chamber, which uses the logarithmic rise in ionization for identification of relativistic particles.

Reconstruction

- 582,000 pictures, which are scanned for nuclear interactions in the thin foils of Mg, Ag, or Au.
  For events with a charged multiplicity of 4-5, the estimated scan efficiency is 92 ± 2% , while for events with more than 5 charged particles it is 96 ± 2% .

- The momentum determination from the bubble chamber measurements alone is good only for low momentum tracks (few GeV/c).

- For faster particles, the momentum is determined by combining the bubble chamber measurements with the 7 planes of proportional chambers (D,E), and 3 drift chamber triplets (F, G, H), using the fringe field of the bubble chamber magnet.

Selection

- Removal of electromagnetic events : in order to eliminate electrons in the beam (contamination of the pion beam) causing pair conversions in the target foils, the events with:

  multiplicity < 9 and **$\log_{10}(\langle q_t^2 \rangle) < -5$**

  are removed from the data sample.

- Removal of coherent events : events which have

  no slow protons (< 1.3 GeV/c) and

  3 or 5 tracks with $y > y_{CM} + 1$

  are removed from the data sample (about 2%).

- Quasi elastic events do not contaminate the data sample as they were not measured.

Particle identification

- momentum < 1.3 GeV/c : the ionization in the bubble chamber is used for particle identification.
  - all fragments heavier than a proton have been labeled as "protons".
  - less than ~5% of real pions are misclassified as "protons";
    less than ~15% of real protons are misclassified as "pions";
    data is corrected for these pion/proton misidentifications.
  - instead, kaons are not identified, so **most of $K^{\pm}$ are called $\pi^{\pm}$**.
  - $e^{\pm}$ with momenta < 200 MeV/c (most of them are due to photon conversions in the target foils) have been removed.
- momentum > 5 GeV/c : the ionization in CRISIS is used for particle id (π/p separation; **most of $K^{\pm}$ are called $\pi^{\pm}$**).
- the **distributions** are **corrected** for:
  1. unidentified $e^{\pm}$ with momenta > 200 MeV/c
  2. unidentified **protons** with momenta between [1.3, 5.0] GeV/c

Measured (corrected) distributions

The following two distributions are measured for all identified produced π^+ and π^- :

- Laboratory rapidity distribution:

$$\frac{1}{N_T}\frac{dN}{dy}$$

where: $y = \frac{1}{2}\ln\left(\frac{E+p_z}{E-p_z}\right)$

N_T = number of event

- Transverse momentum squared:

$$\frac{1}{N_T}\frac{dN}{dP_T^2}$$

where: N_T = number of event

Some numbers

- Dimension of the target foils:

foil	Mg	Mg	Ag	Ag	Au	Au
thickness (mm)	3.7	11.1	0.6	1.8	0.3	0.9
Width (mm)	9	9	14	9	17	9
λ (%)	0.5	1.5	0.3	0.9	0.3	0.9

- Number of selected events:

beam		Mg	Ag	Au
100 GeV/c	π^-	283	773	668
	π^+	83	212	179
	K^+	21	55	60
	p	58	352	180
	$\underline{p}$	218	582	465
320 GeV/c	π^-	51	140	130

Simulation

- Geant4 8.1.p01 , physics lists: LHEP, QGSP and QGSC; Fluka2006.3 (October version) with PEATHRES.
- Target : 1 mm x 1 μm x 1 μm .
- Consider all the tracks at 1 cm distance from the origin, excluding $e^{\pm}$ / γ with momentum < 200 MeV/c .
- Apply:
  - remove tracks with momenta < "reconstruction threshold" (0-100 MeV/c);
  - cut to remove "electromagnetic events" (few%, due to δ-rays);
  - cut to remove "coherent events" (including heavier fragments as "protons" in the definition of "coherent event") (≤1%).
- Calculate y and P_T^2 for $\pi^{\pm}$ and $K^{\pm}$ using always π mass to calculate the rapidity.

Checks

A number of checks have been carried out to study the stability of the results:

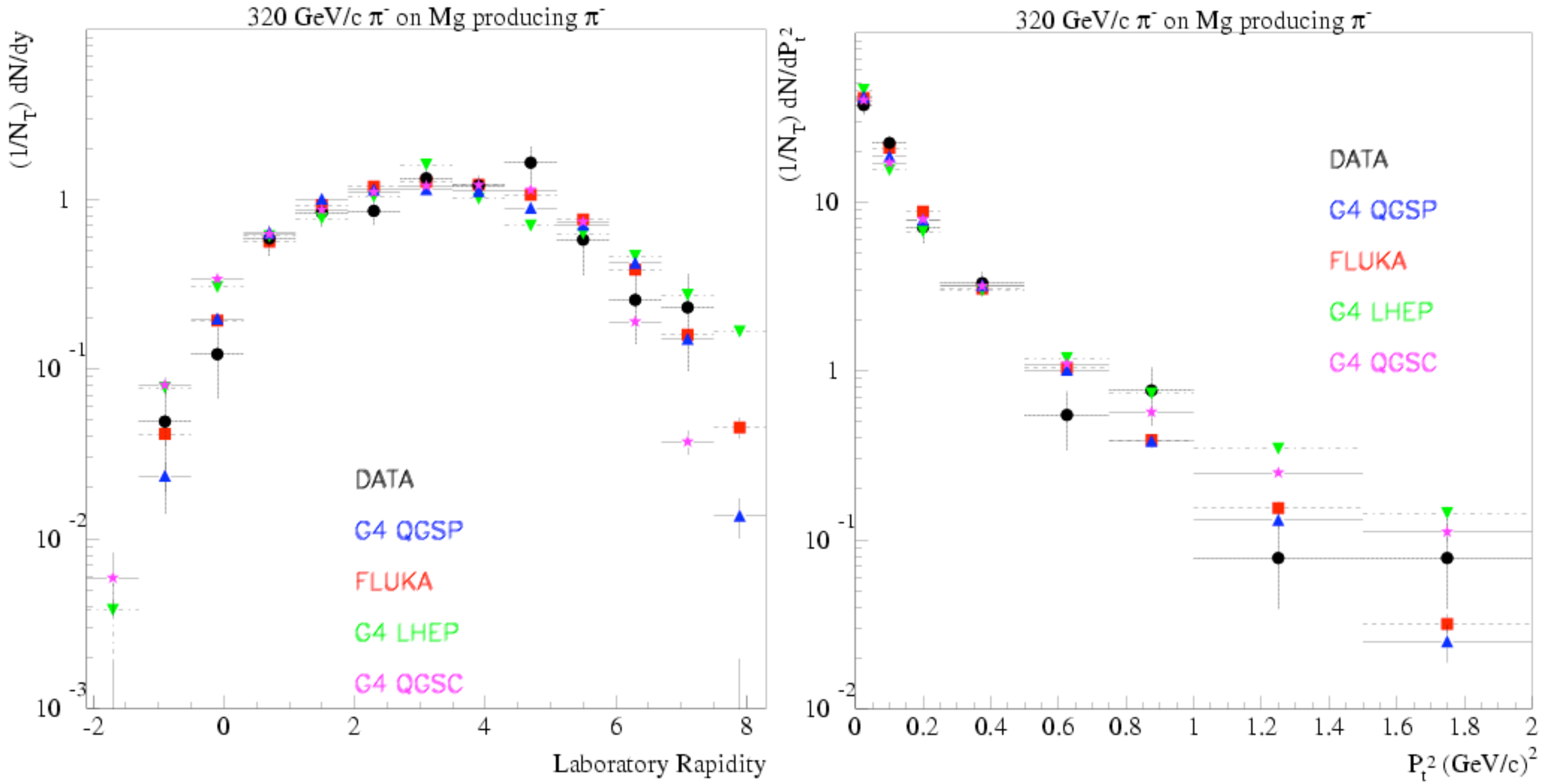
- variations of the "reconstruction threshold";
- change of the size of the target foil;
- removal of events with secondary hadronic interactions;
- only pure protons in the definition of "coherent event";
- K^+ misidentification as "proton" in the definition of "coherent event";
- Variation of the $K^\pm$ misidentification as $\pi^\pm$ from 50% to 100%.

Results of the simulations

Number of selected events, from 1,000,000 generated events:

		QGSP	LHEP	FLUKA
100 GeV/c Mg	π-	1387	1417	1282
	π+	1305	1367	1269
	K+	1122	1157	1130
	p	1749	1766	1685
	p_	1732	1741	1704
Ag	π-	5232	5486	5295
	π+	5399	5225	5356
	K+	4977	5083	5028
	p	6623	6477	6695
	_p	5961	6045	6728
Au	π-	8302	8559	8134
	π+	8413	8220	8185
	K+	7899	8063	7639
	p	9799	9859	9903
	p_	8804	8799	10212
320 GeV/c Mg	π-	1285	1644	1322
Ag	π-	5418	6250	5393
Au	π-	8518	9740	7991

π^- production by 320 *GeV/c* π^- on **Mg**



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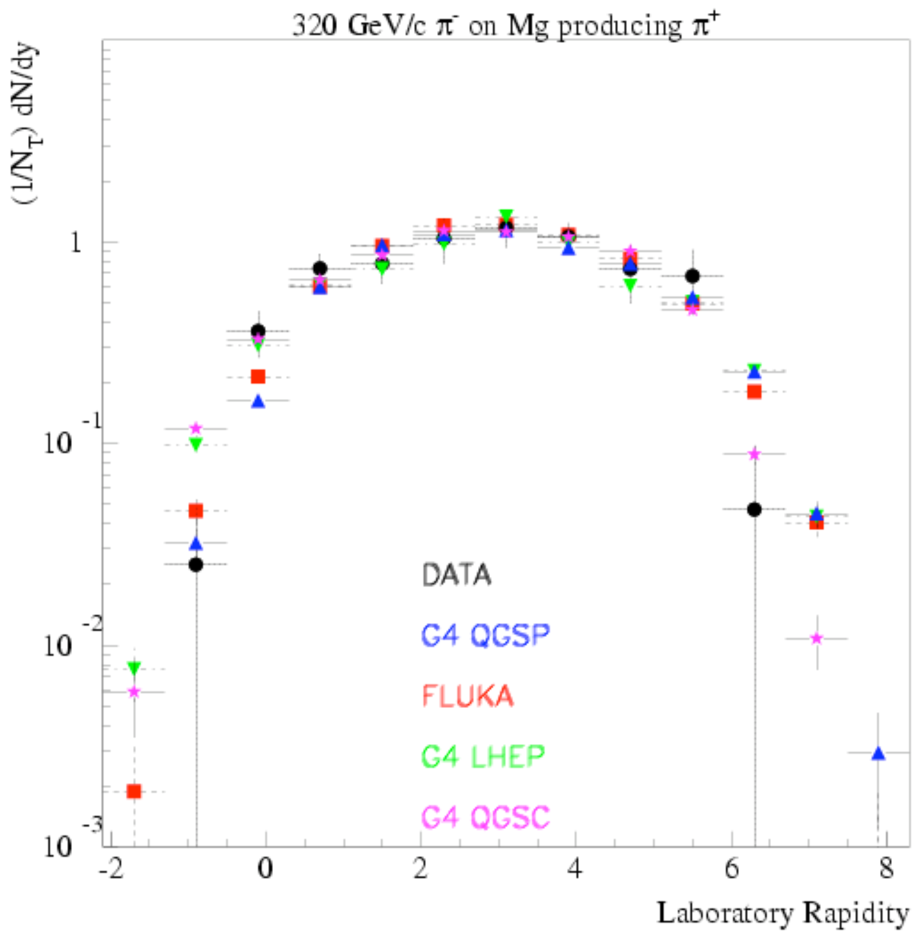
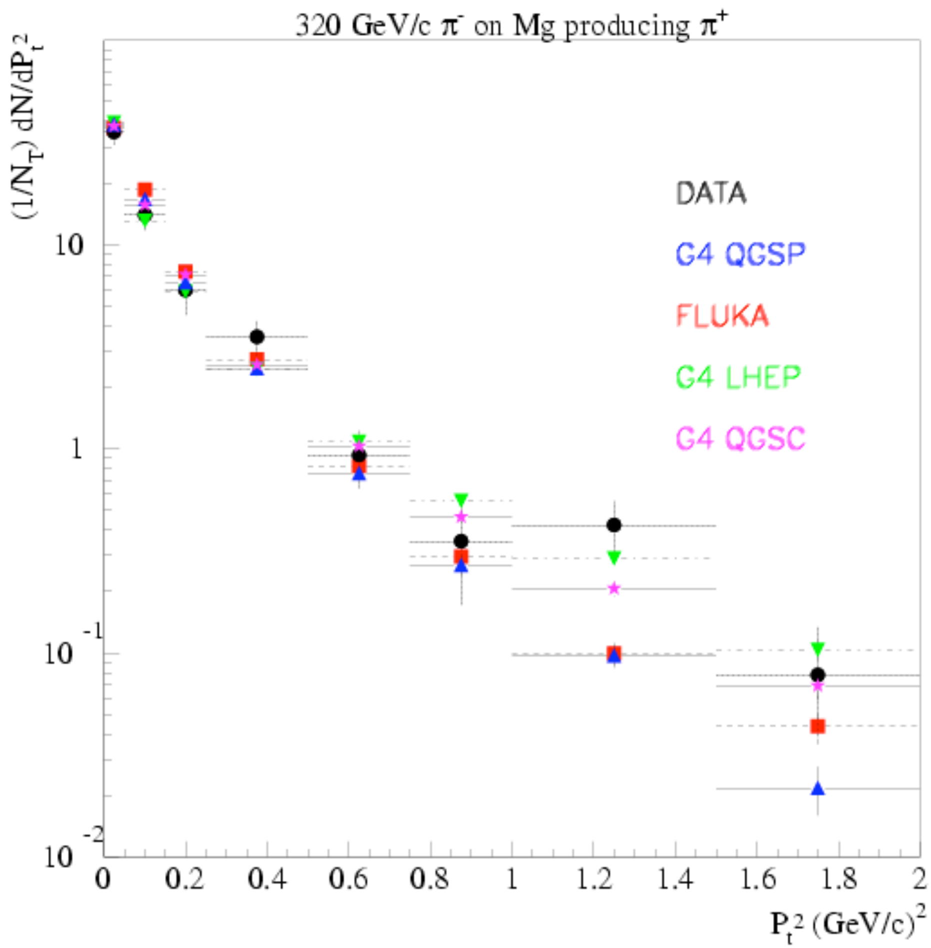
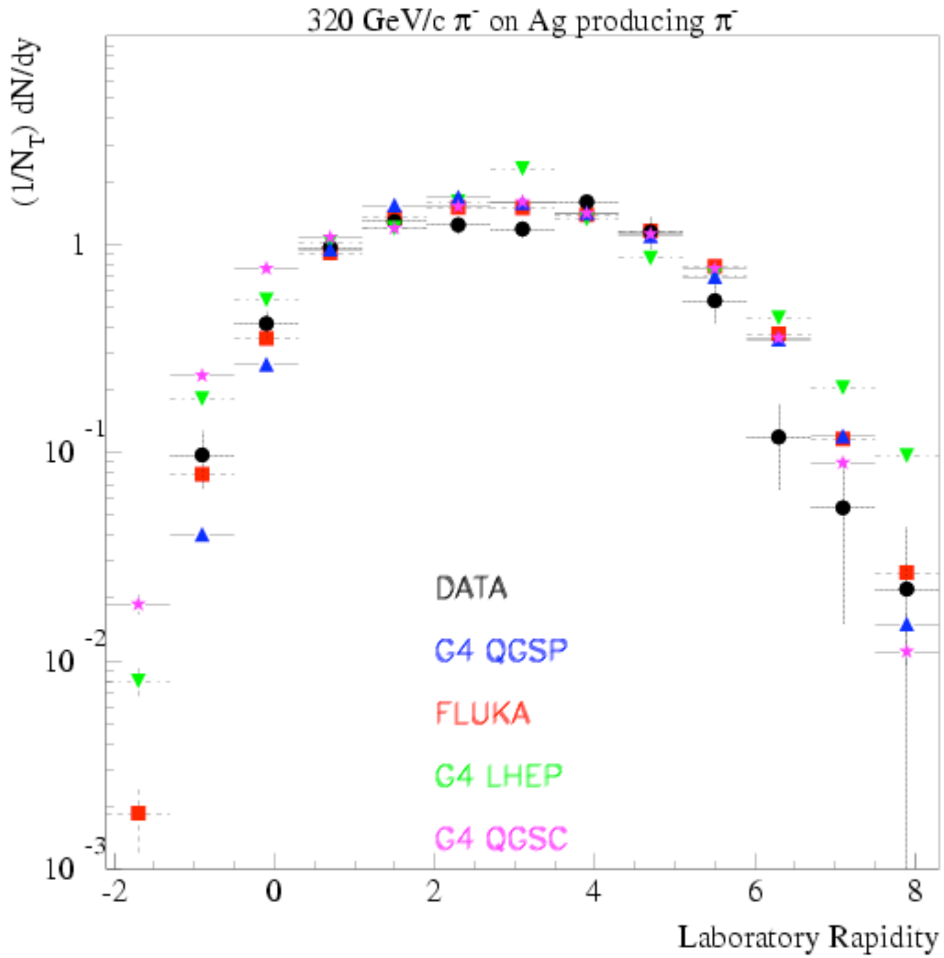
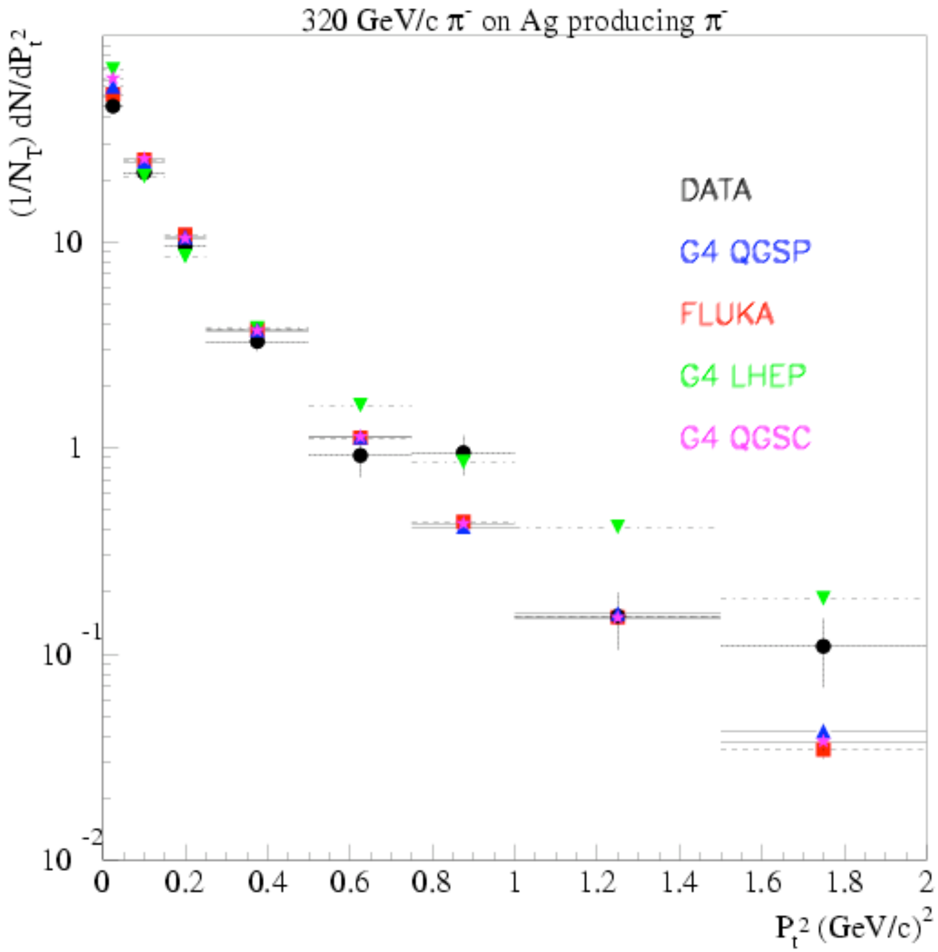
π^+ production by 320 *GeV/c* π^- on Mg





π^- production by 320 *GeV/c* π^- on Ag





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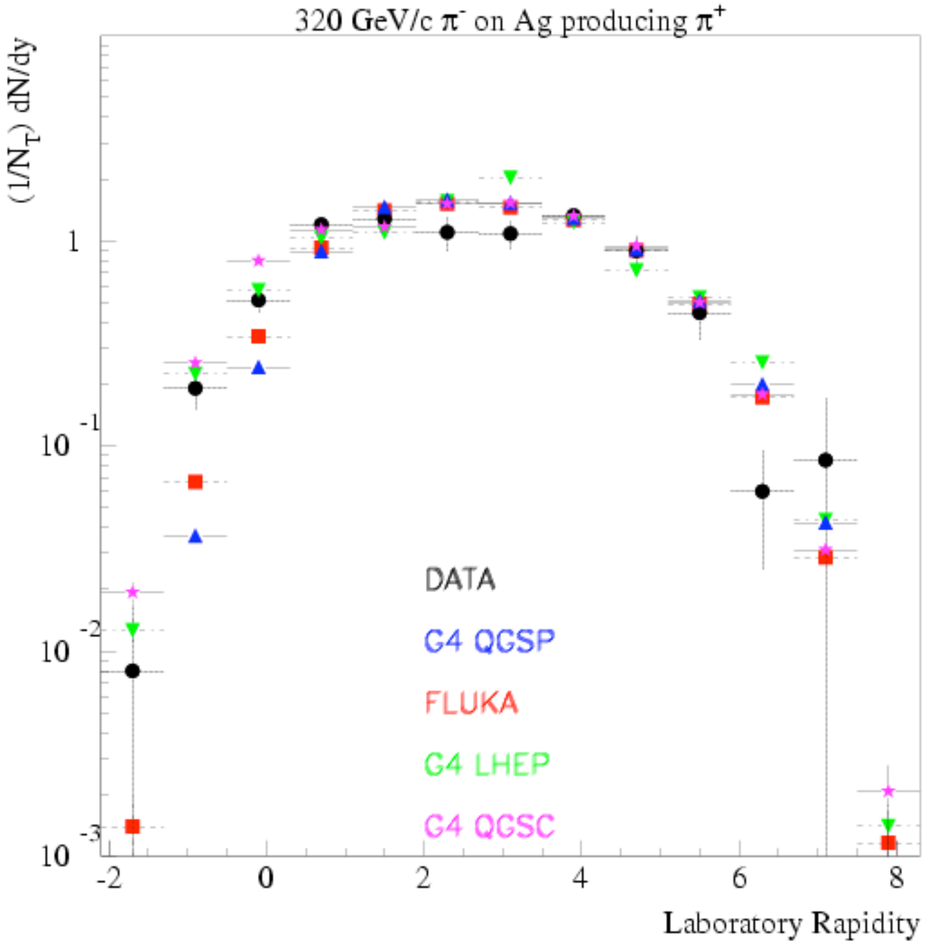
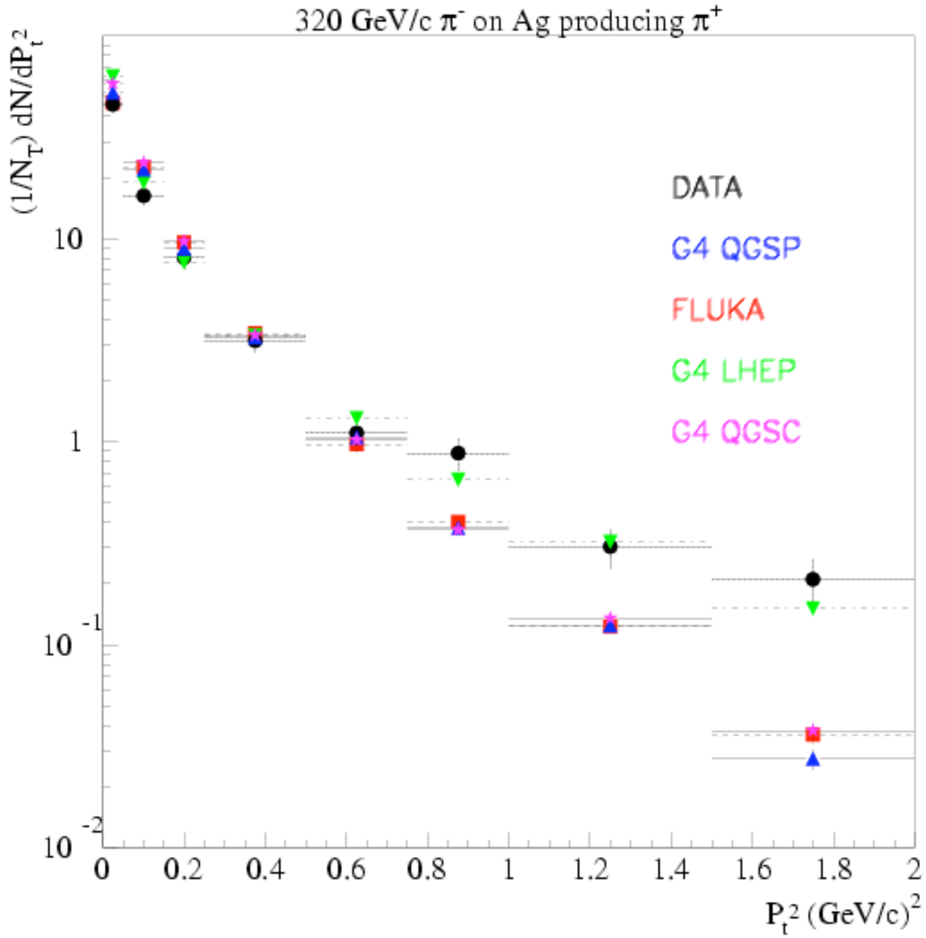
π^+ production by 320 GeV/c π^- on Ag





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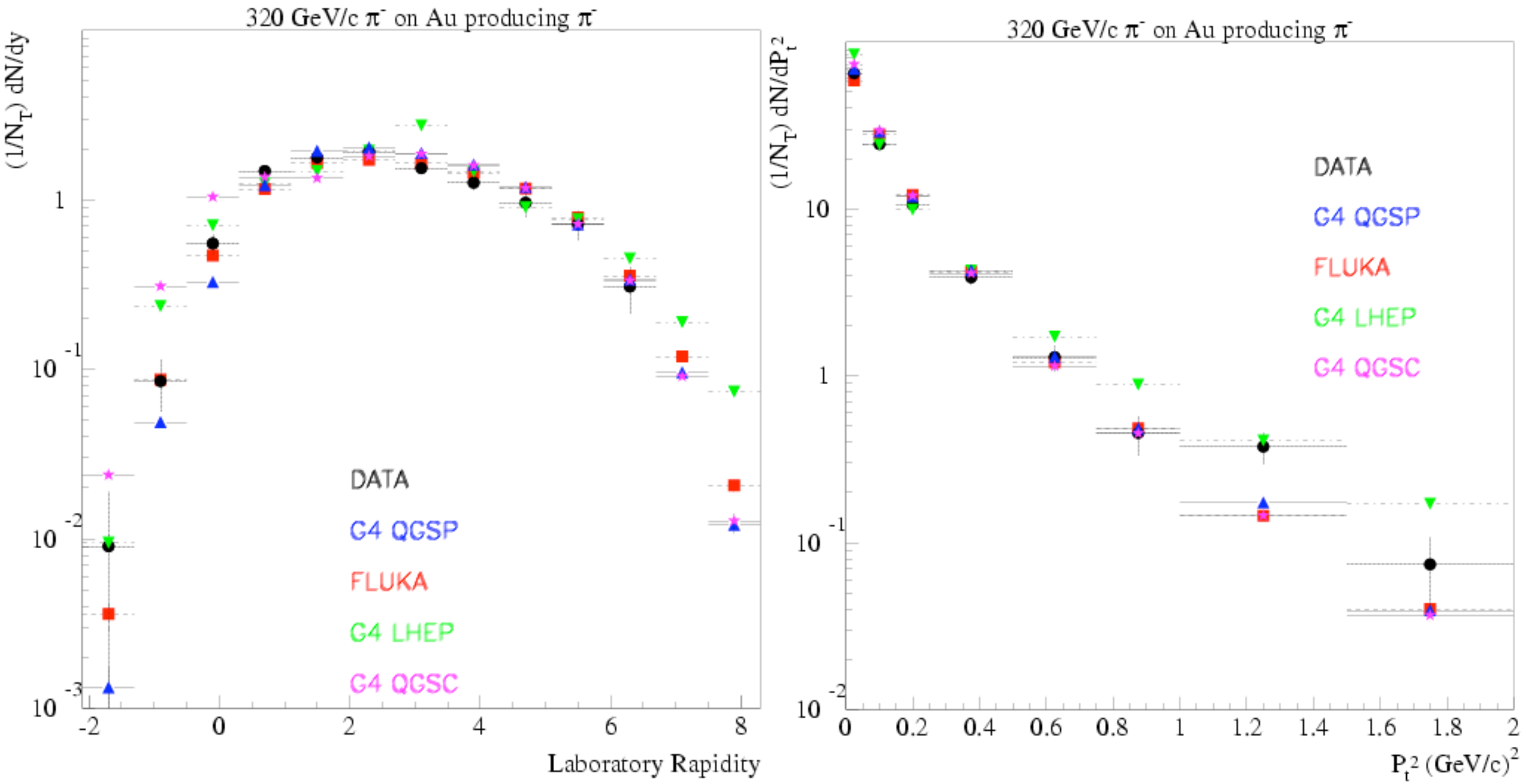
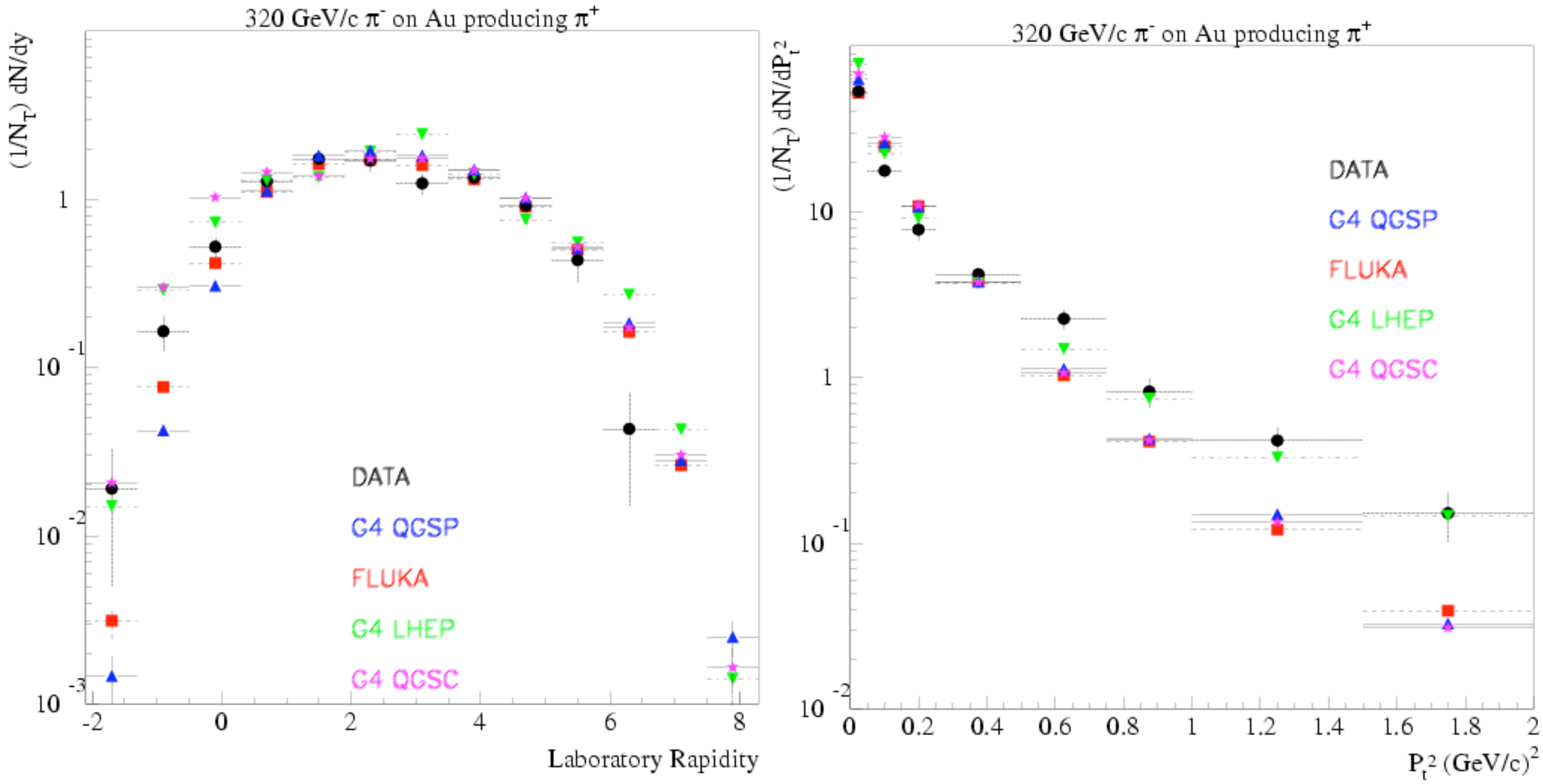
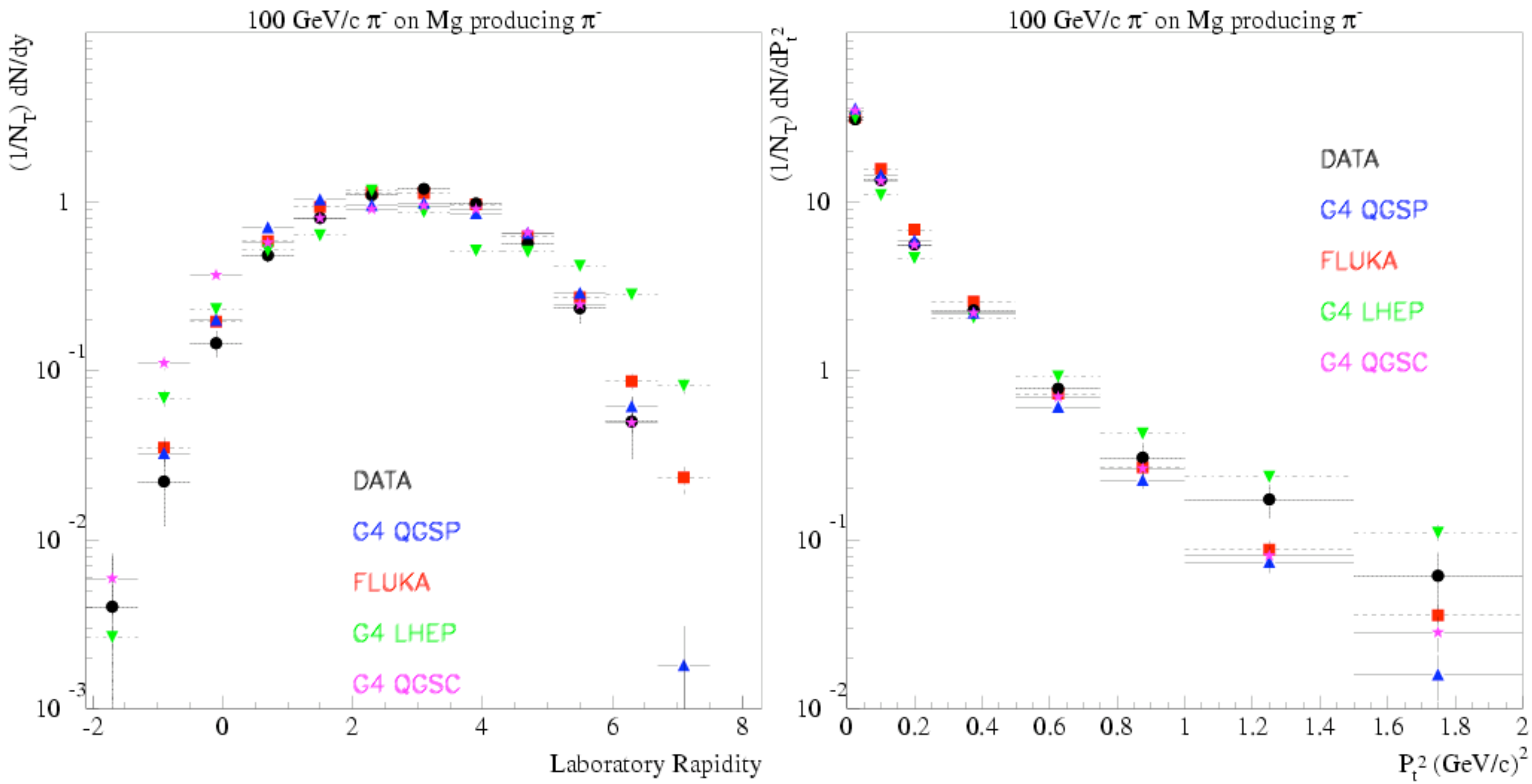
π^- production by 320 GeV/c π^- on Au



π^+ production by 320 GeV/c π^- on Au



π^- production by 100 GeV/c π^- on Mg



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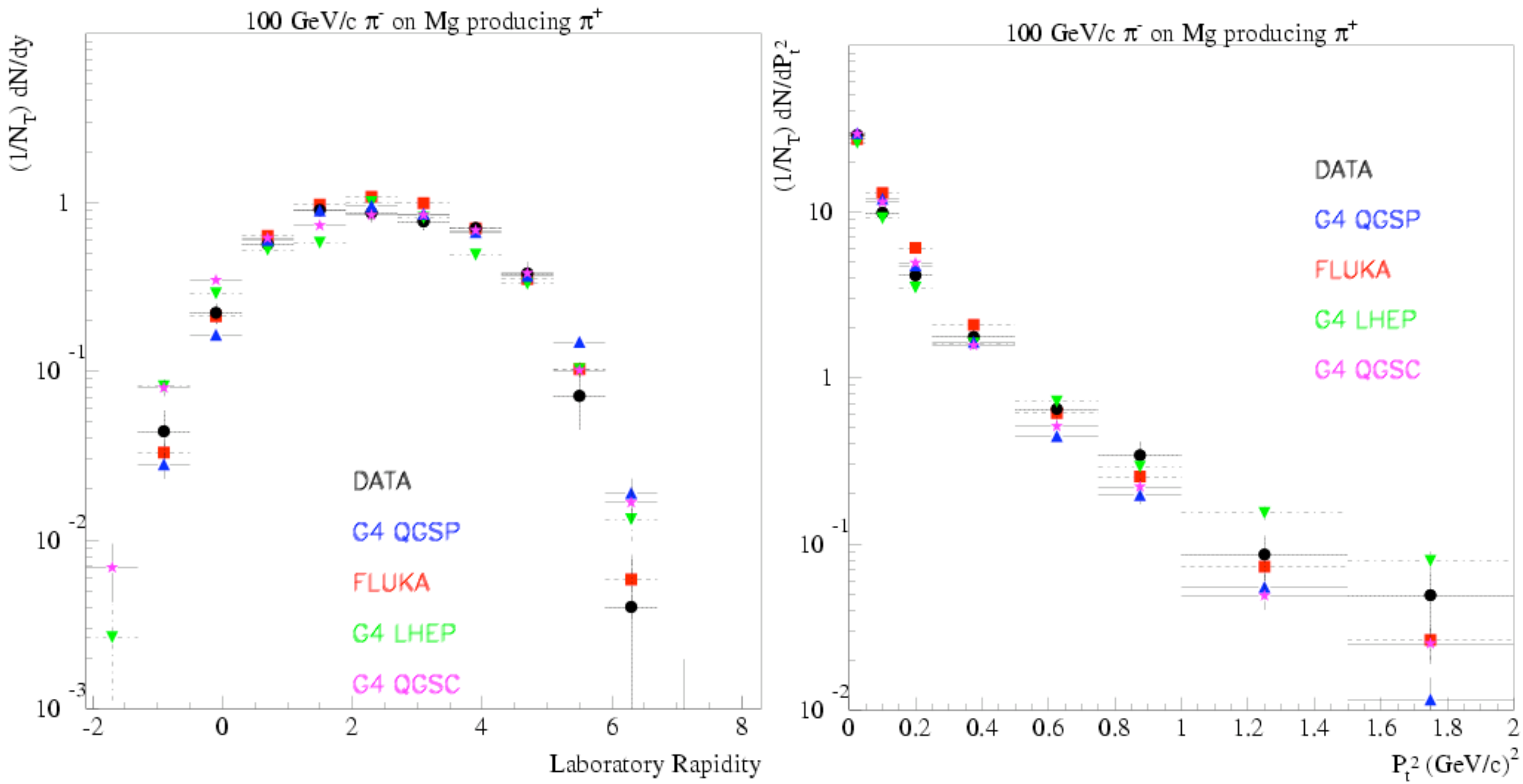
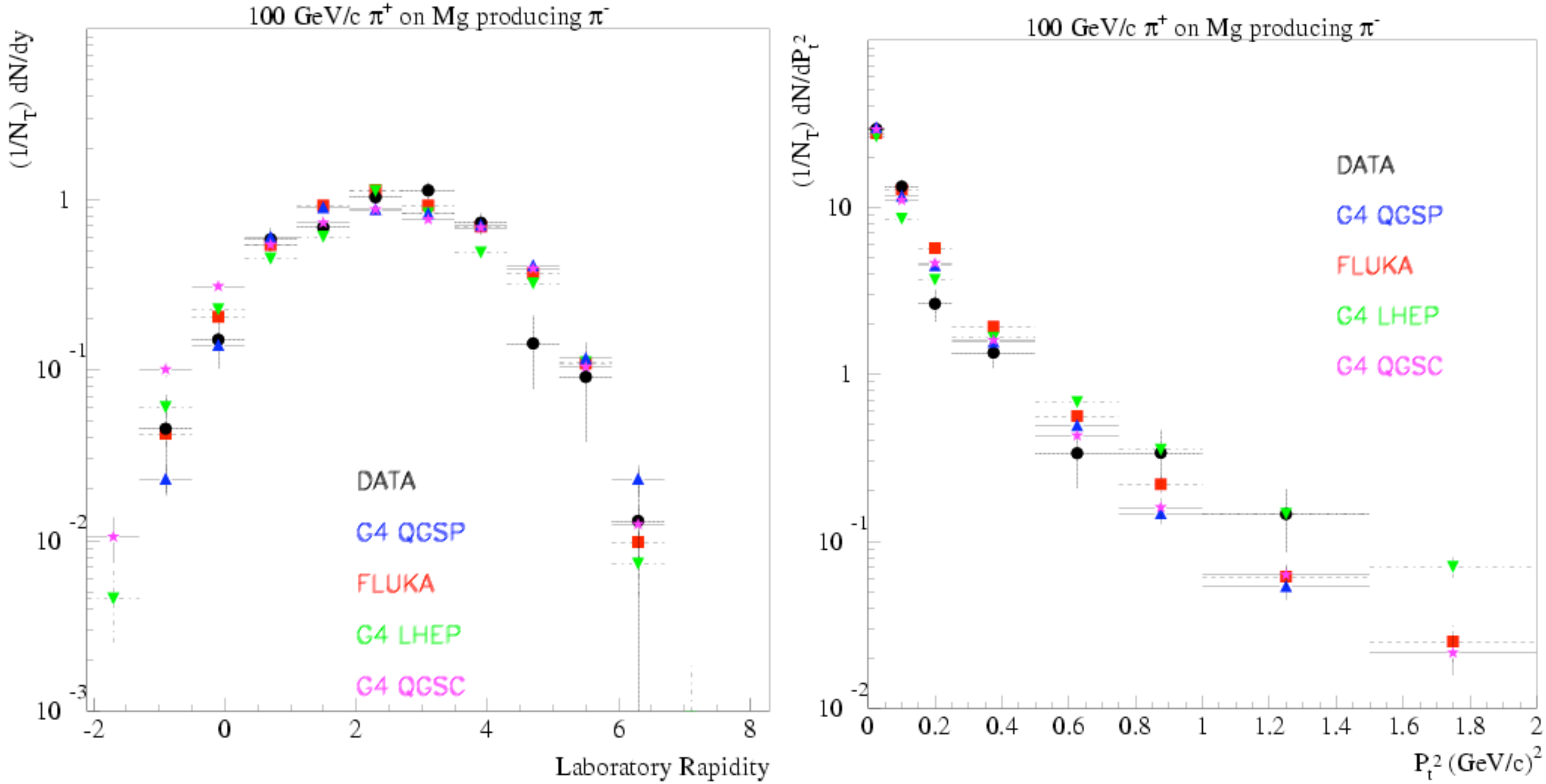
π^+ production by 100 GeV/c π^- on Mg



π^- production by 100 GeV/c π^+ on Mg



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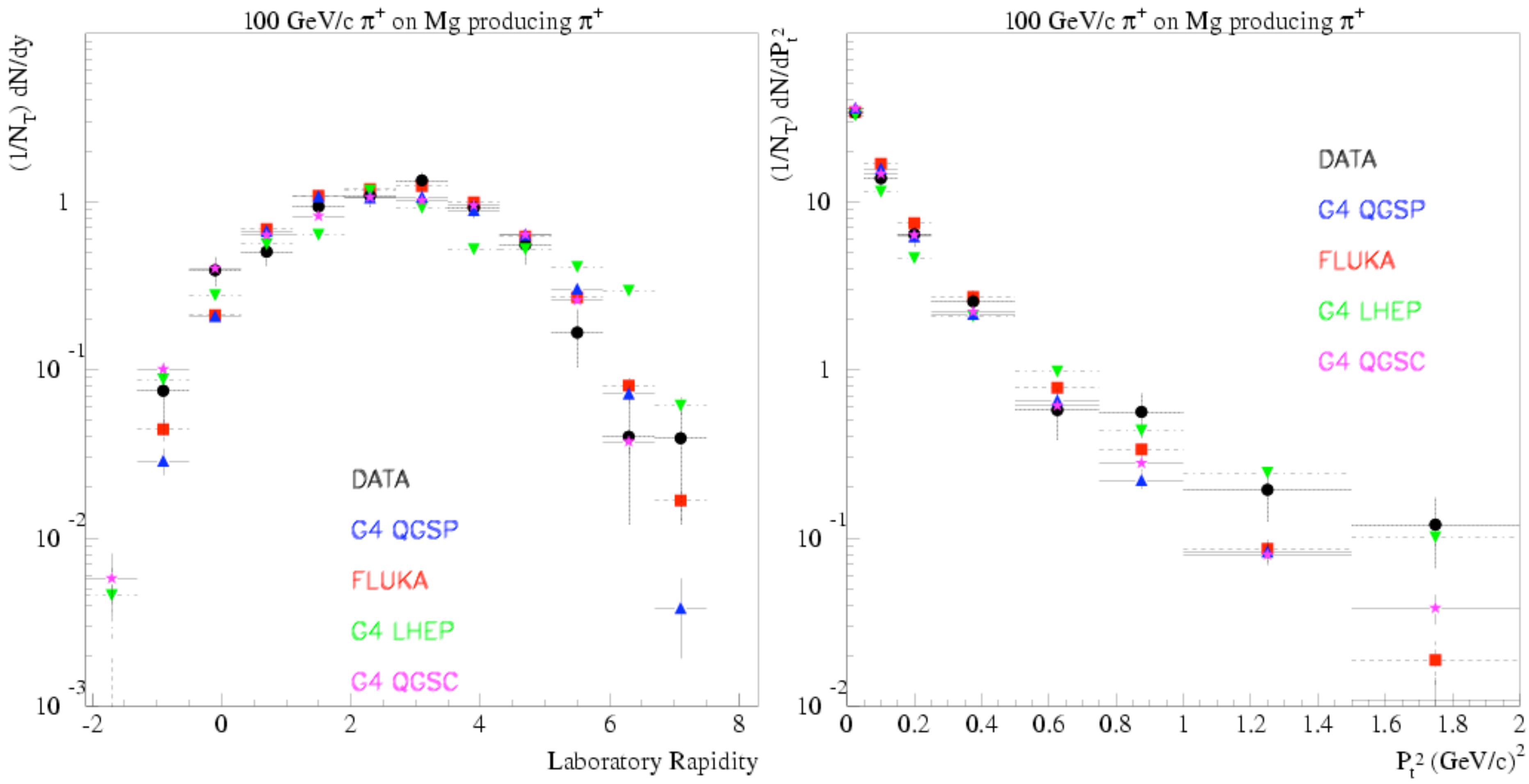
π^+ production by 100 GeV/c π^+ on Mg



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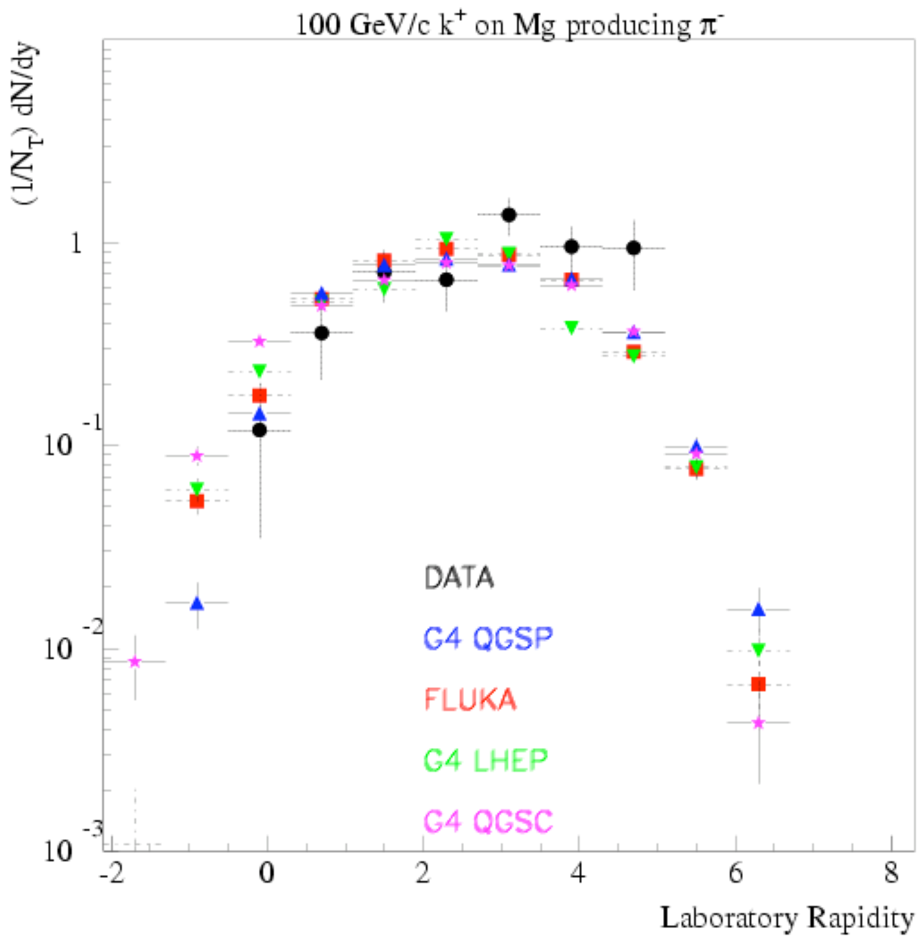
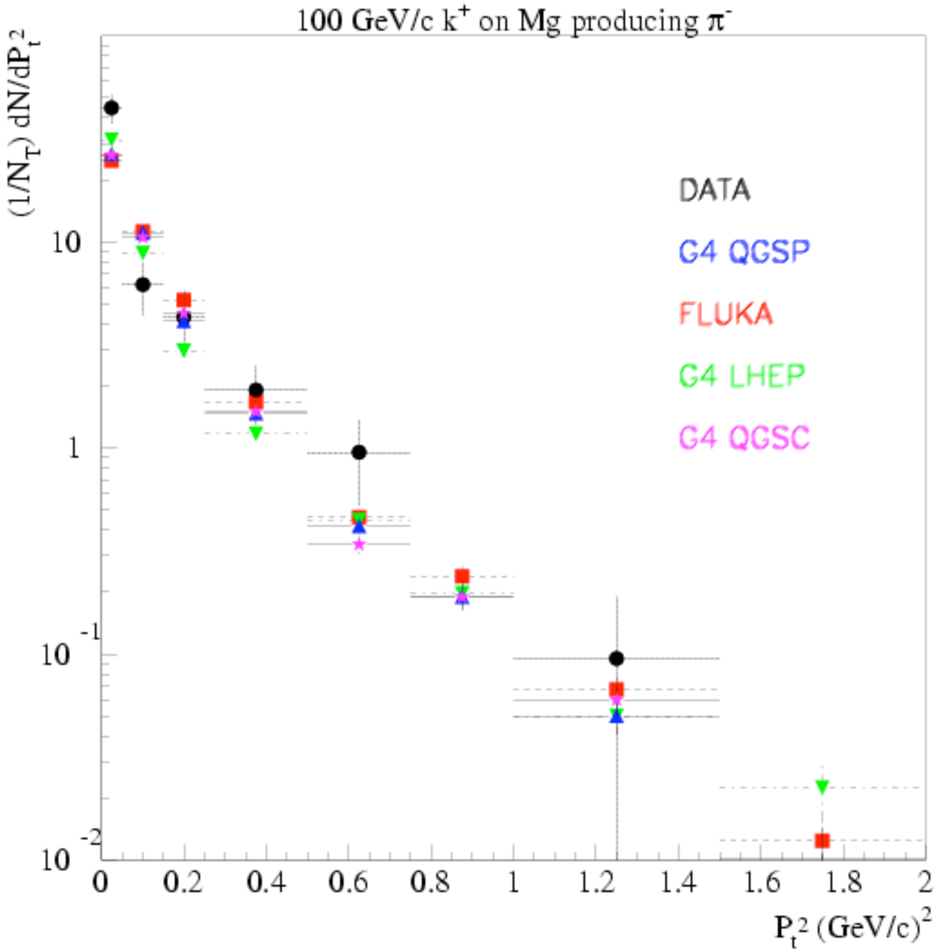
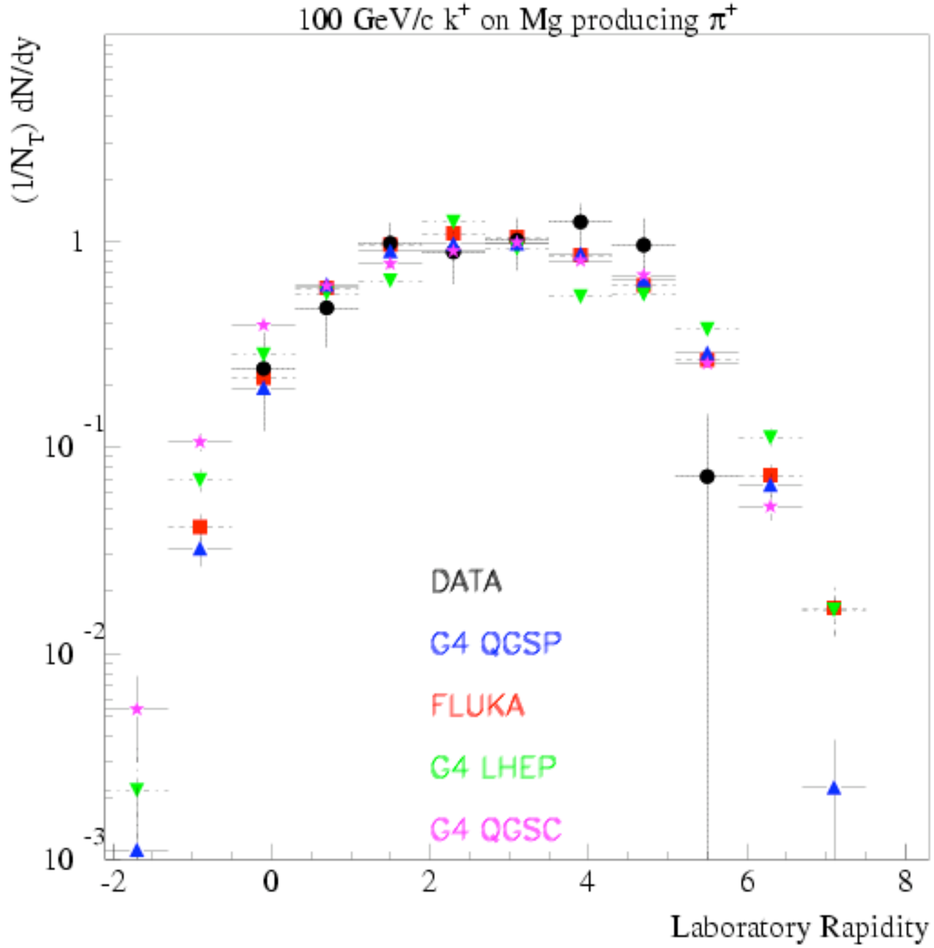
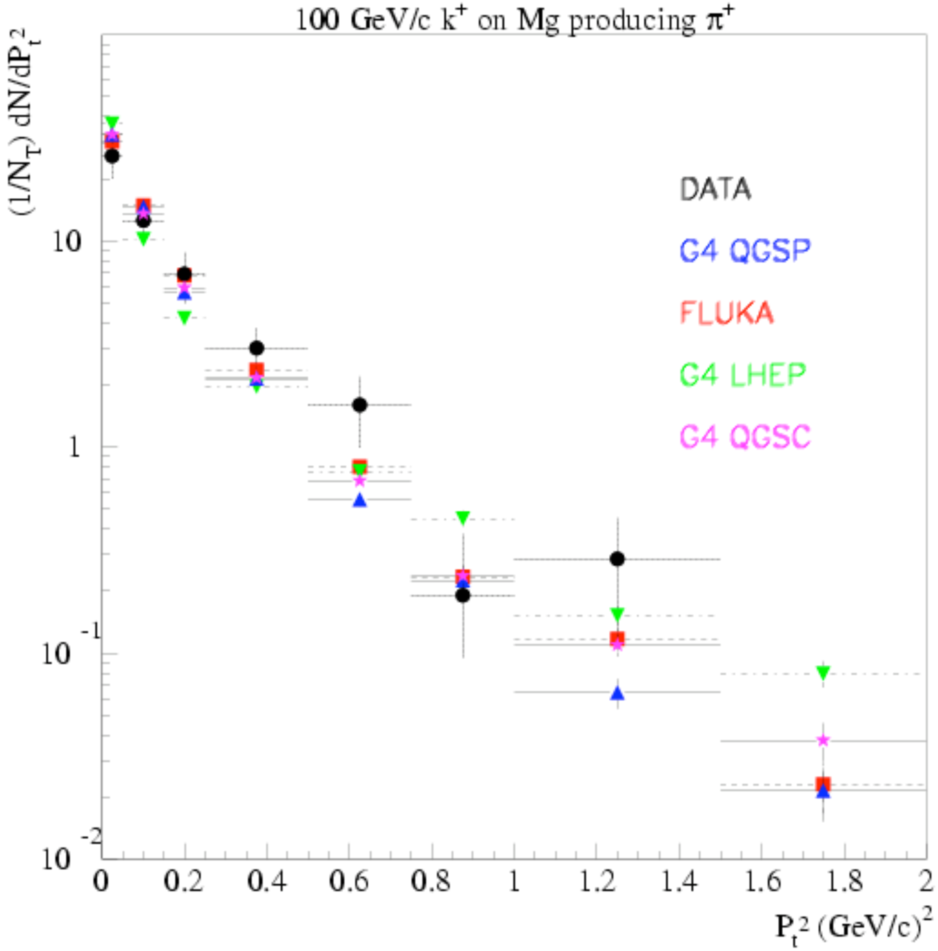
π^- production by 100 GeV/c K^+ on Mg



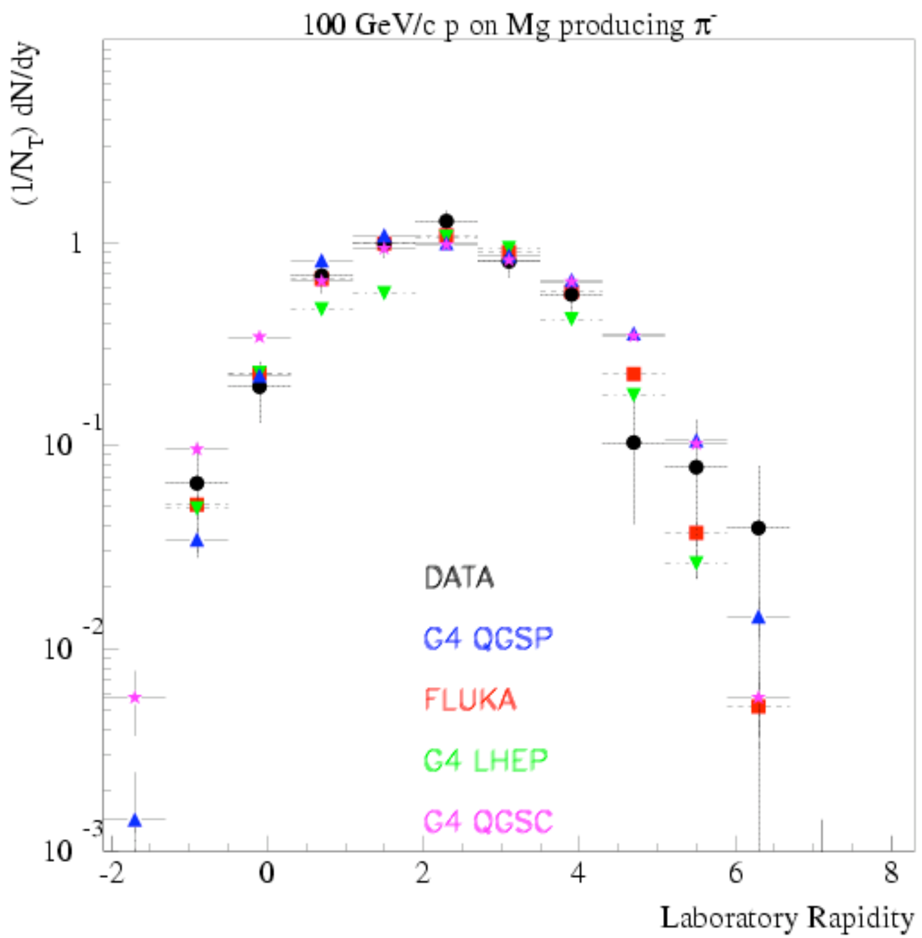


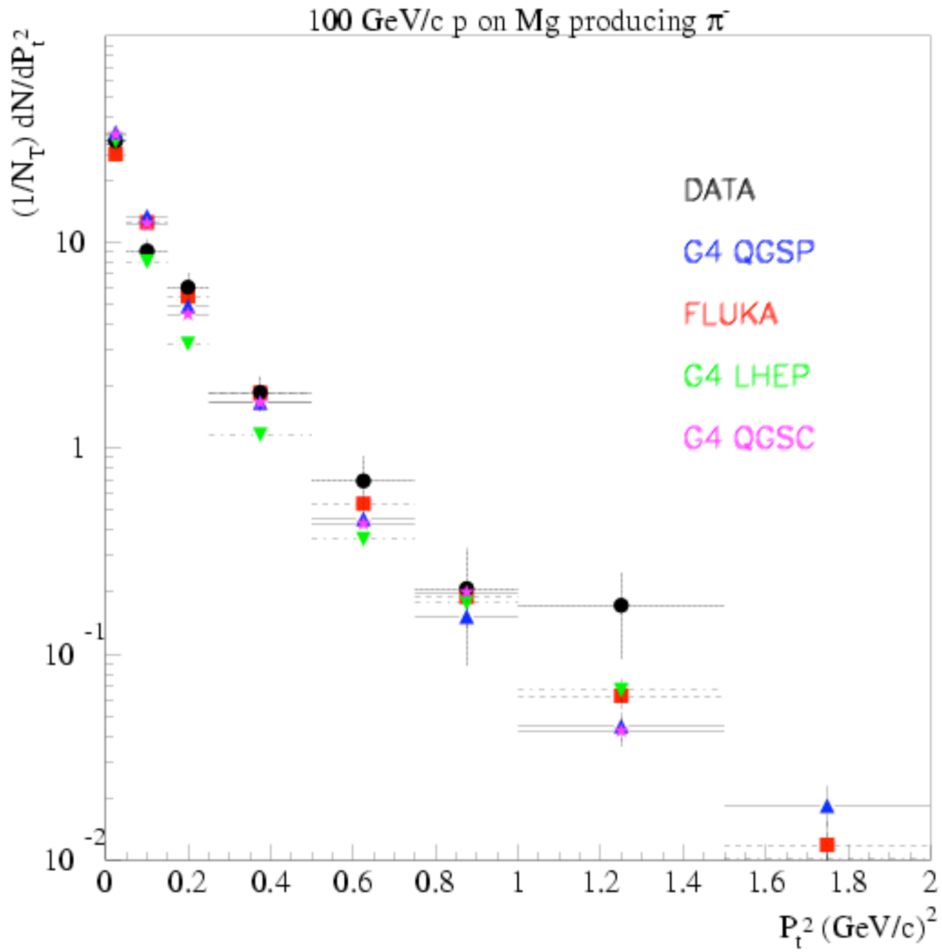
π^+ production by 100 GeV/c K^+ on Mg





π^- production by 100 *GeV/c* **p** on **Mg**





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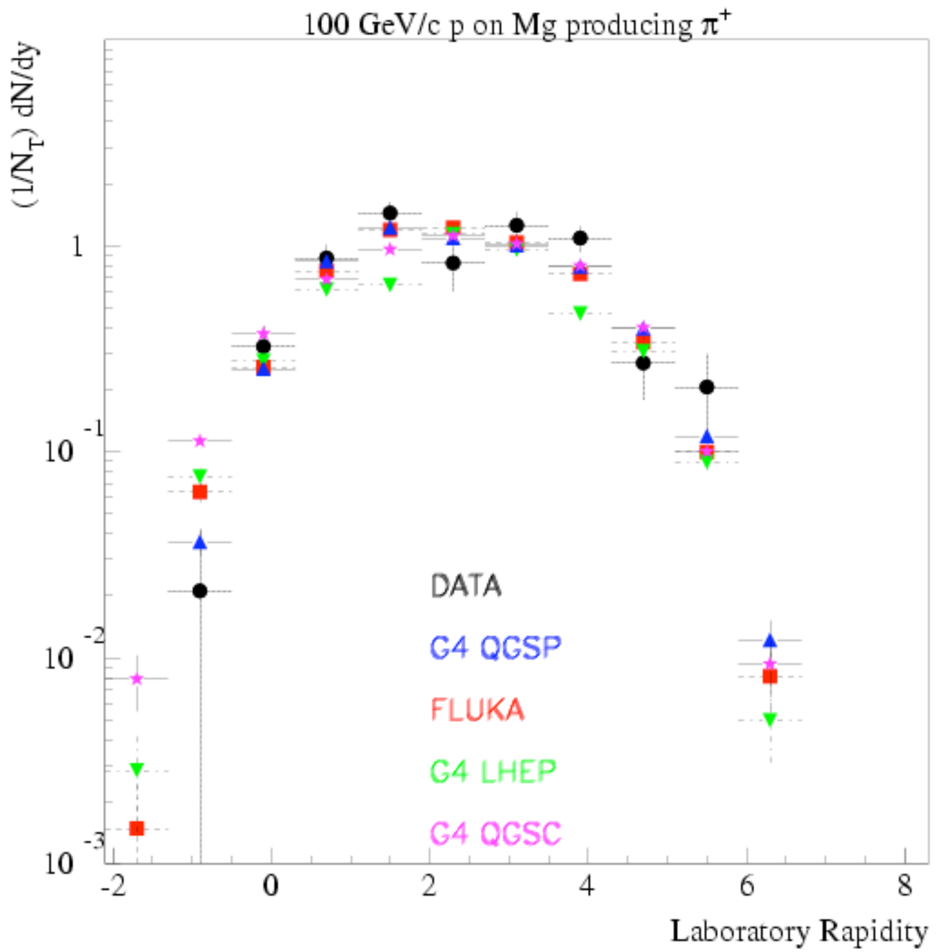
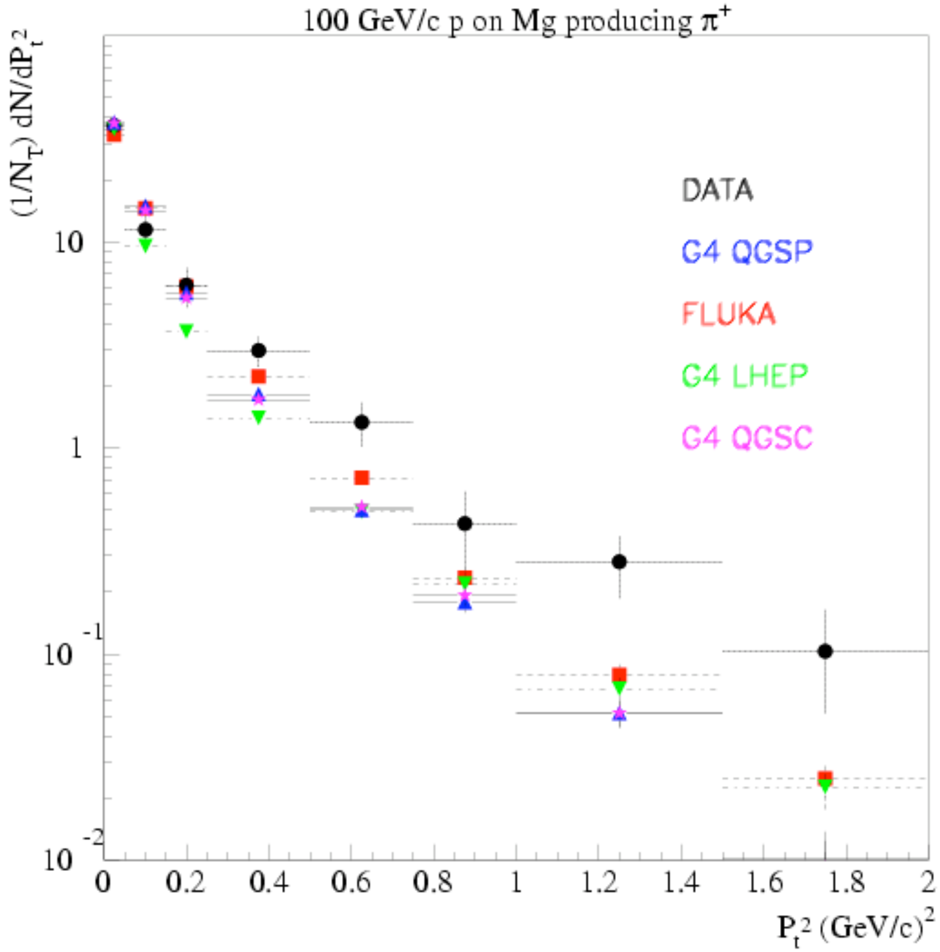
π^+ production by 100 GeV/c p on Mg





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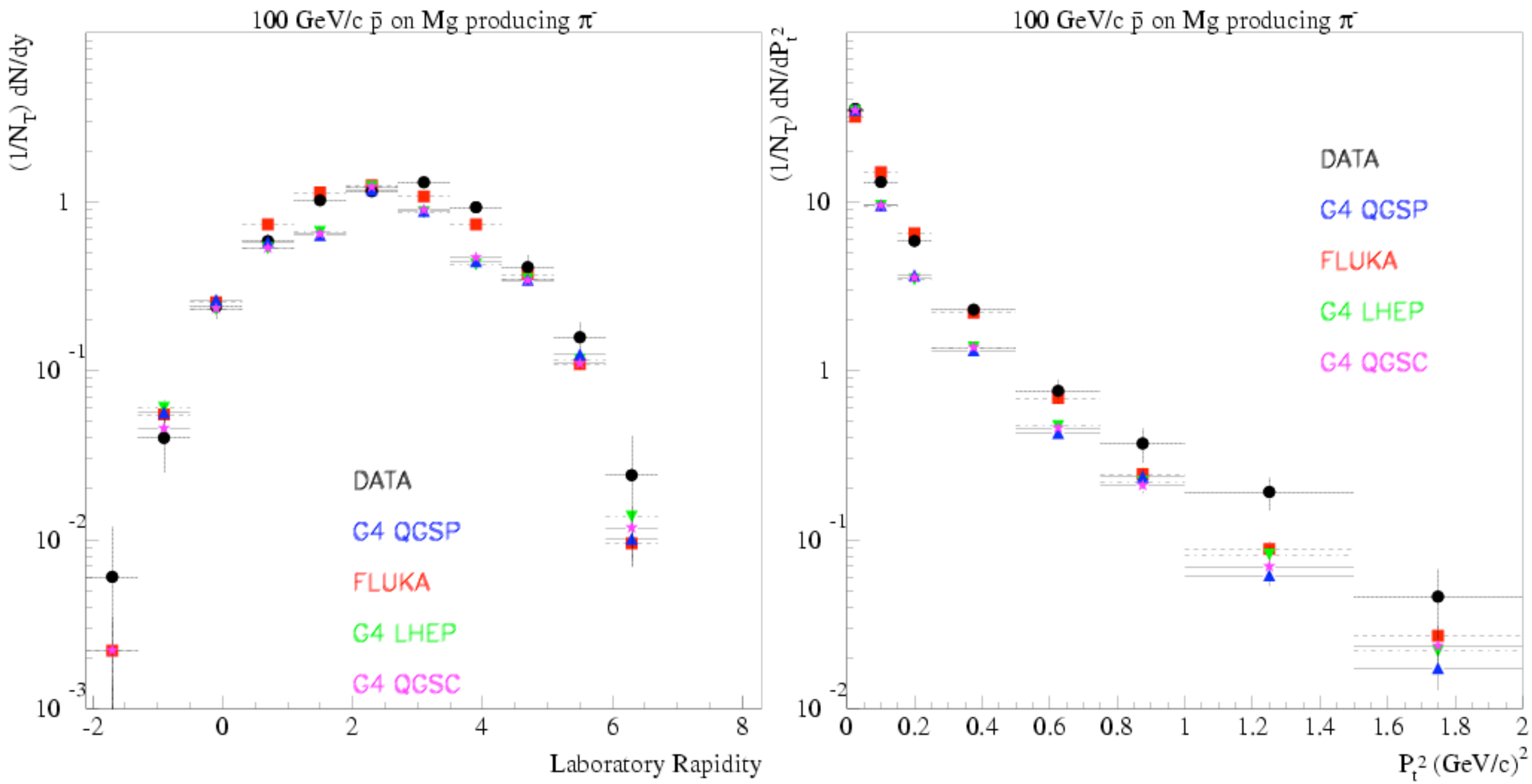
π^- production by 100 *GeV/c* **p** on **Mg**



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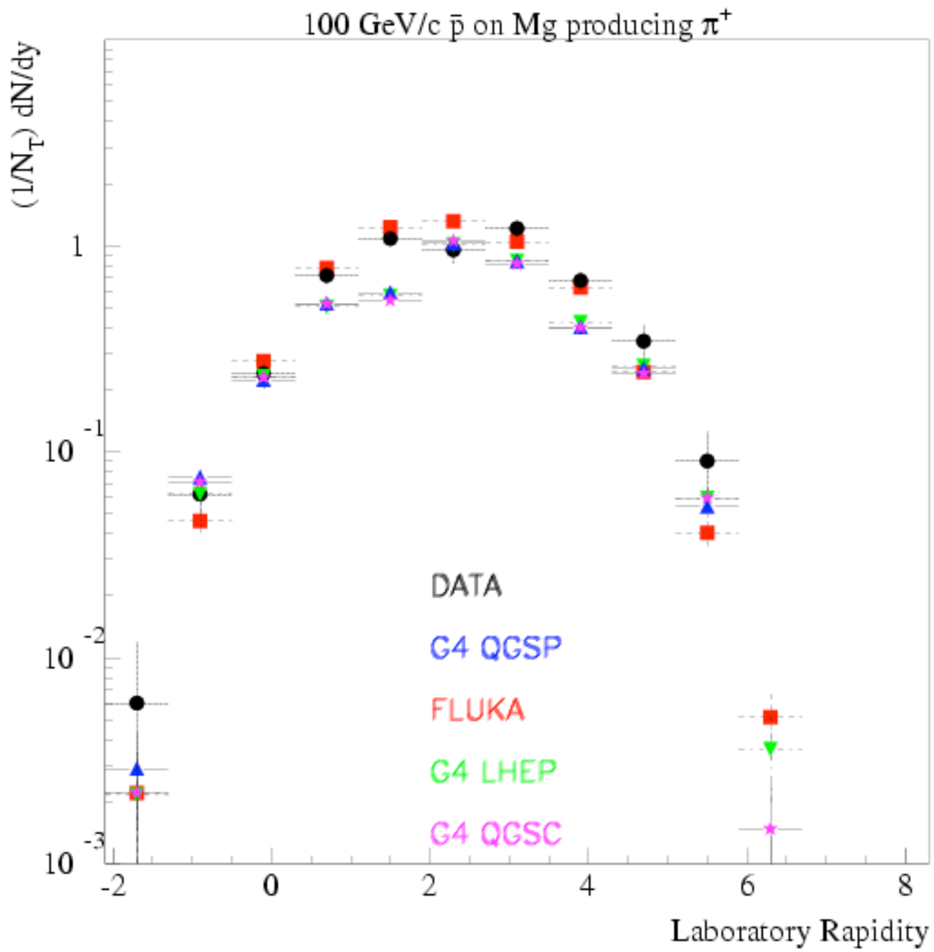
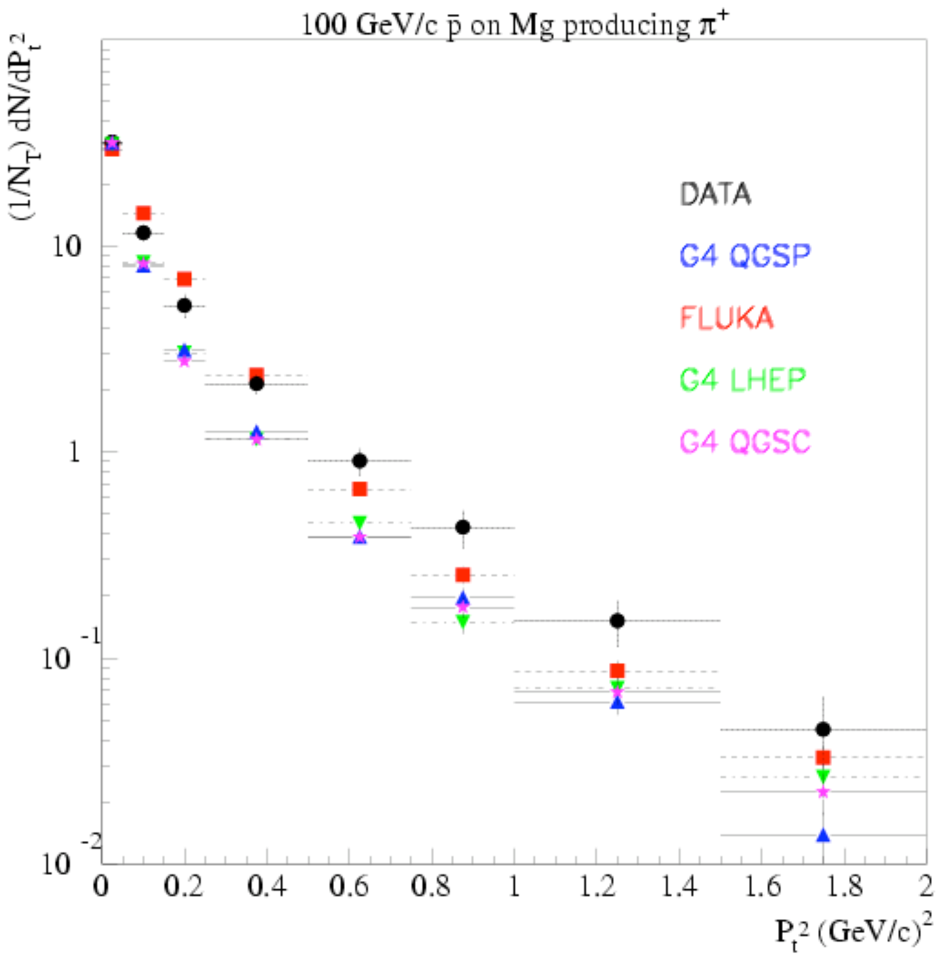
π^+ production by 100 GeV/c p on Mg





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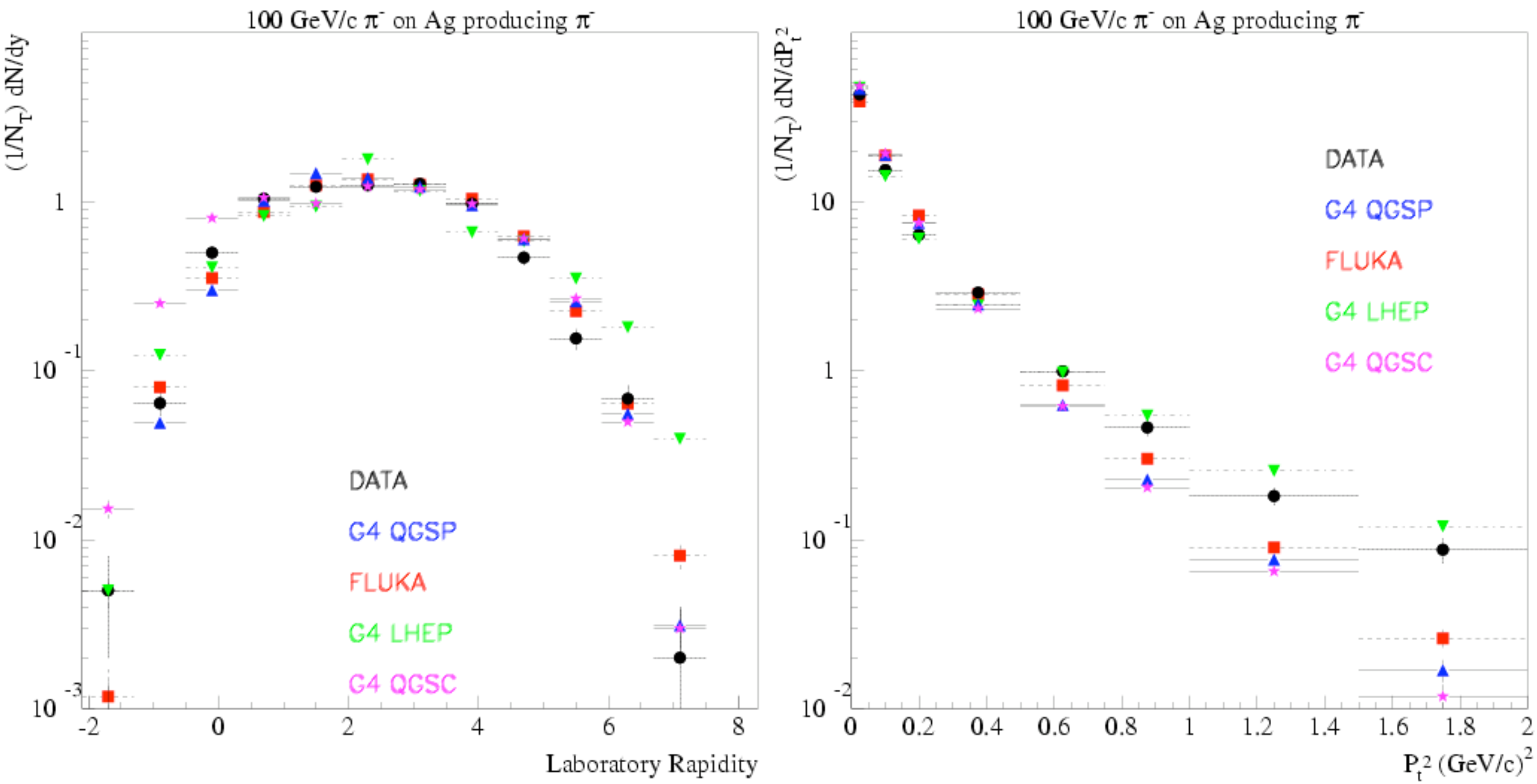
π^- production by 100 GeV/c π^- on Ag



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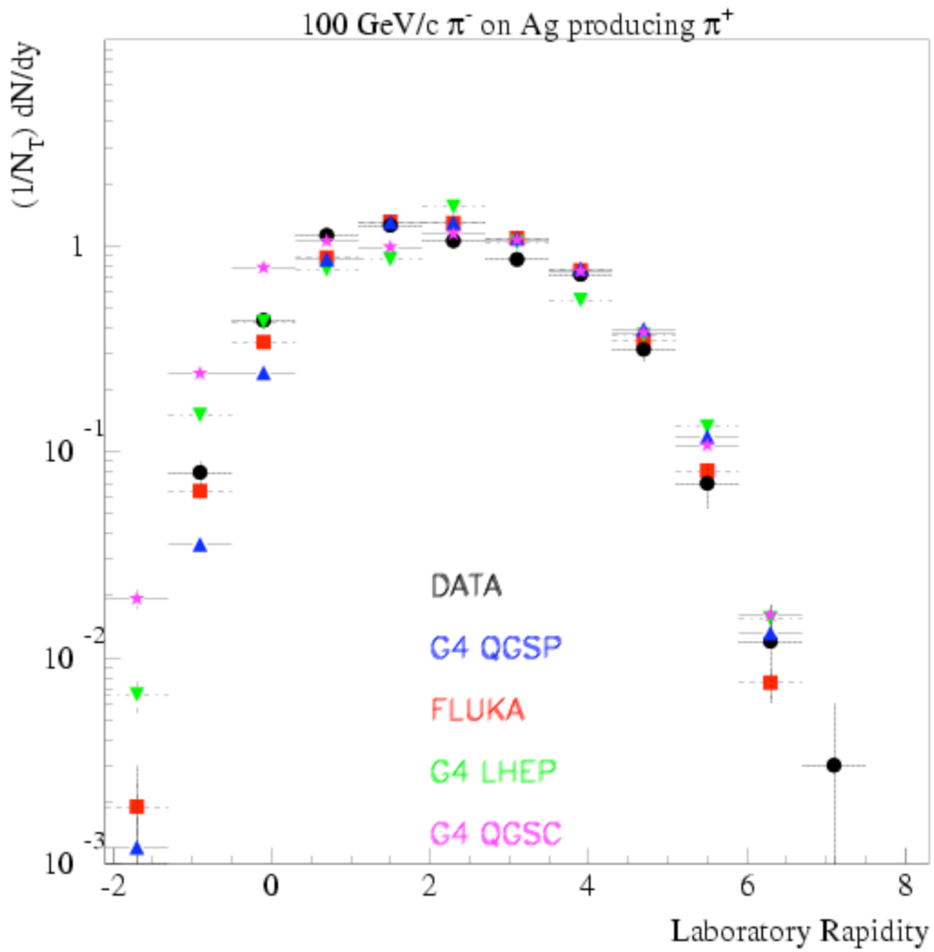
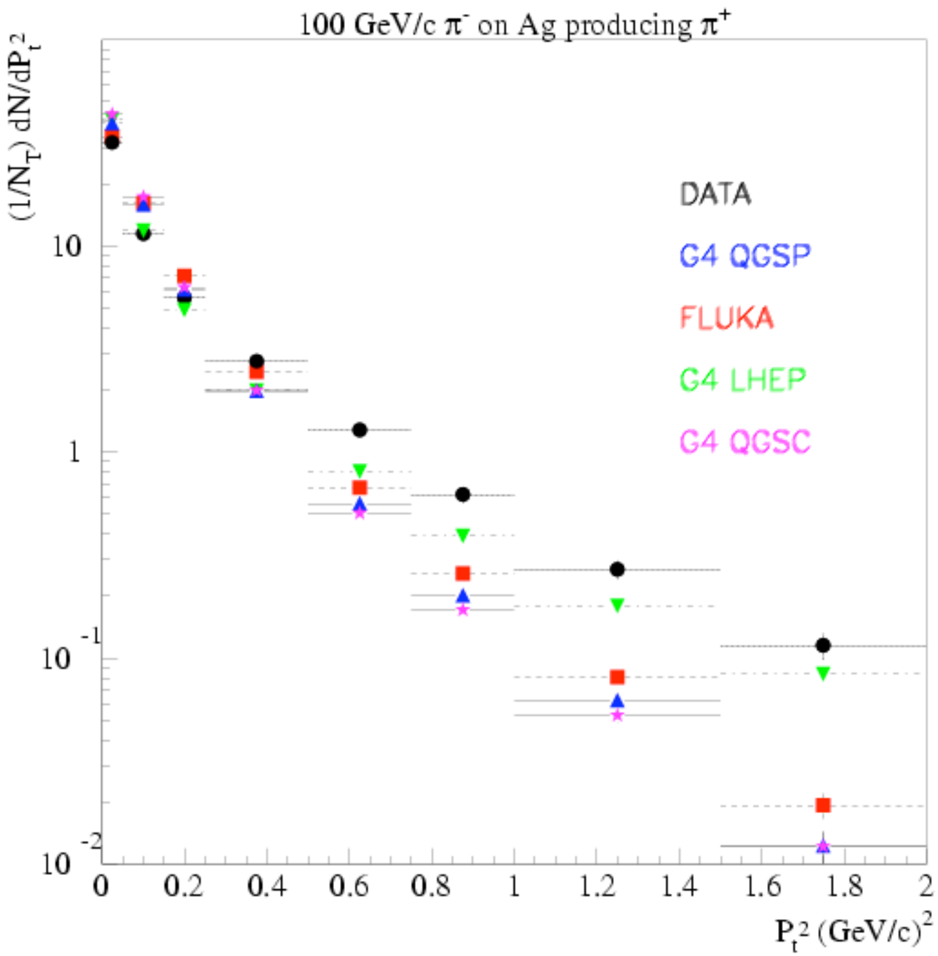
π^+ production by 100 GeV/c π^- on Ag





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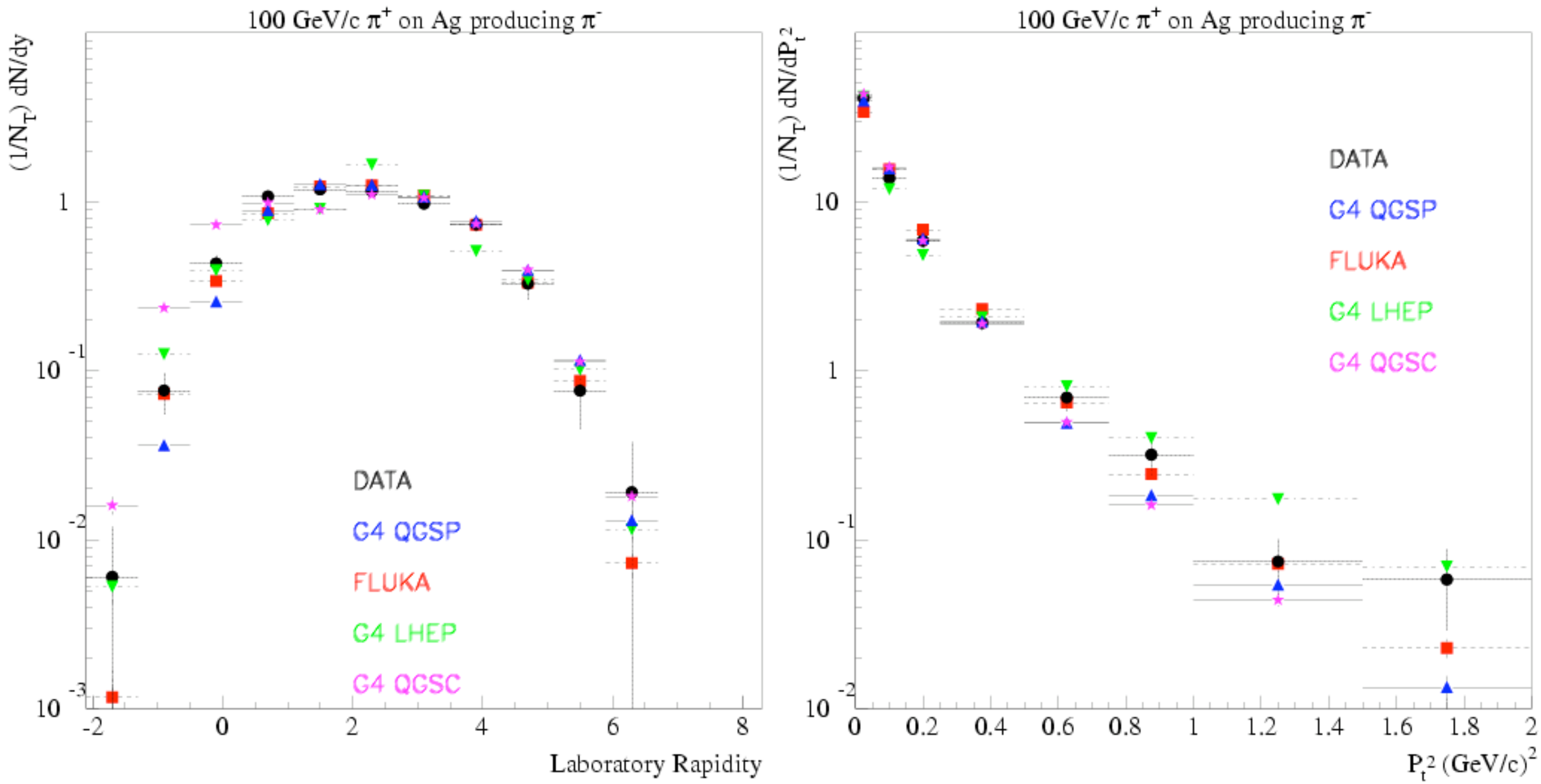
π^- production by 100 GeV/c π^+ on Ag



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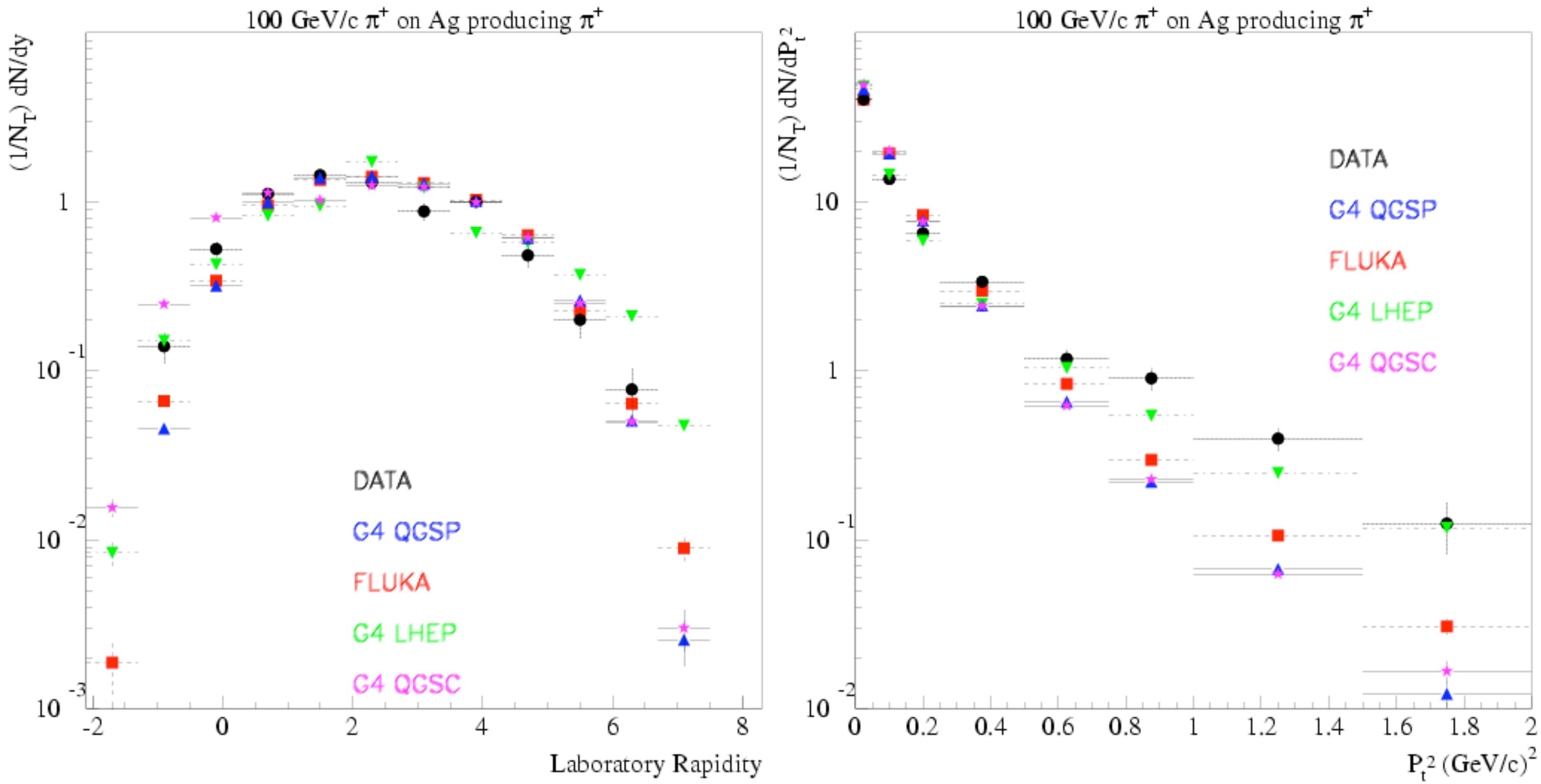
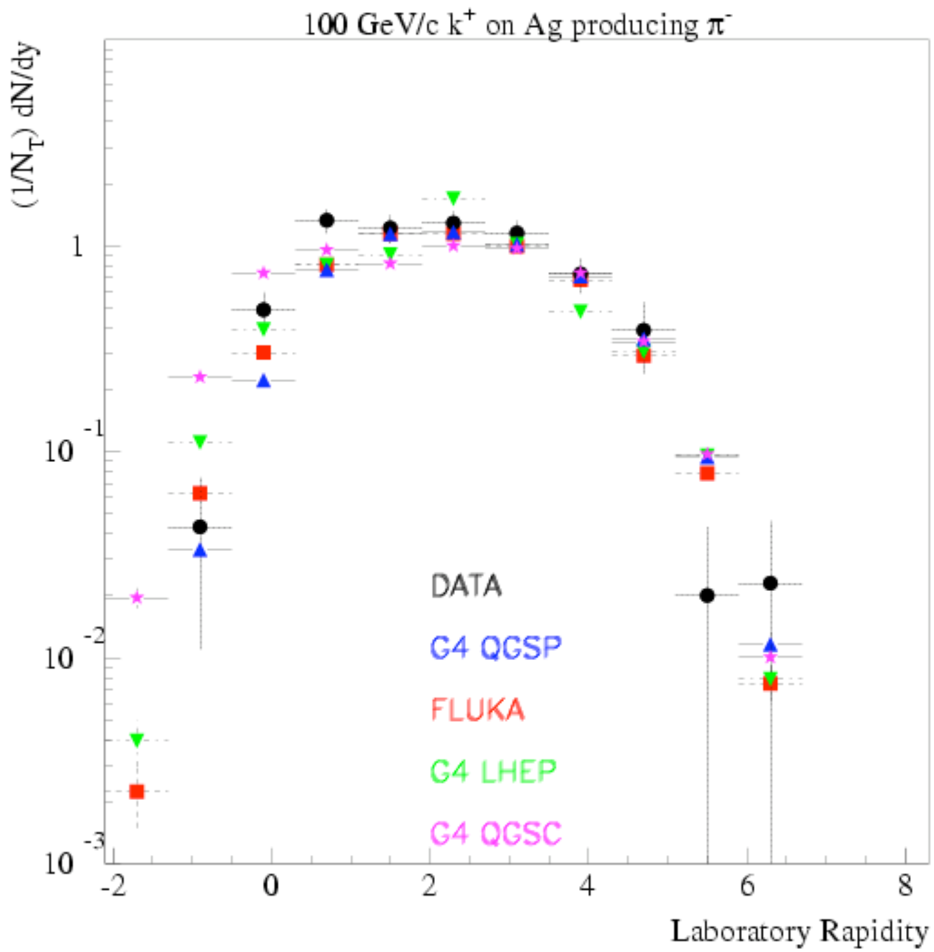
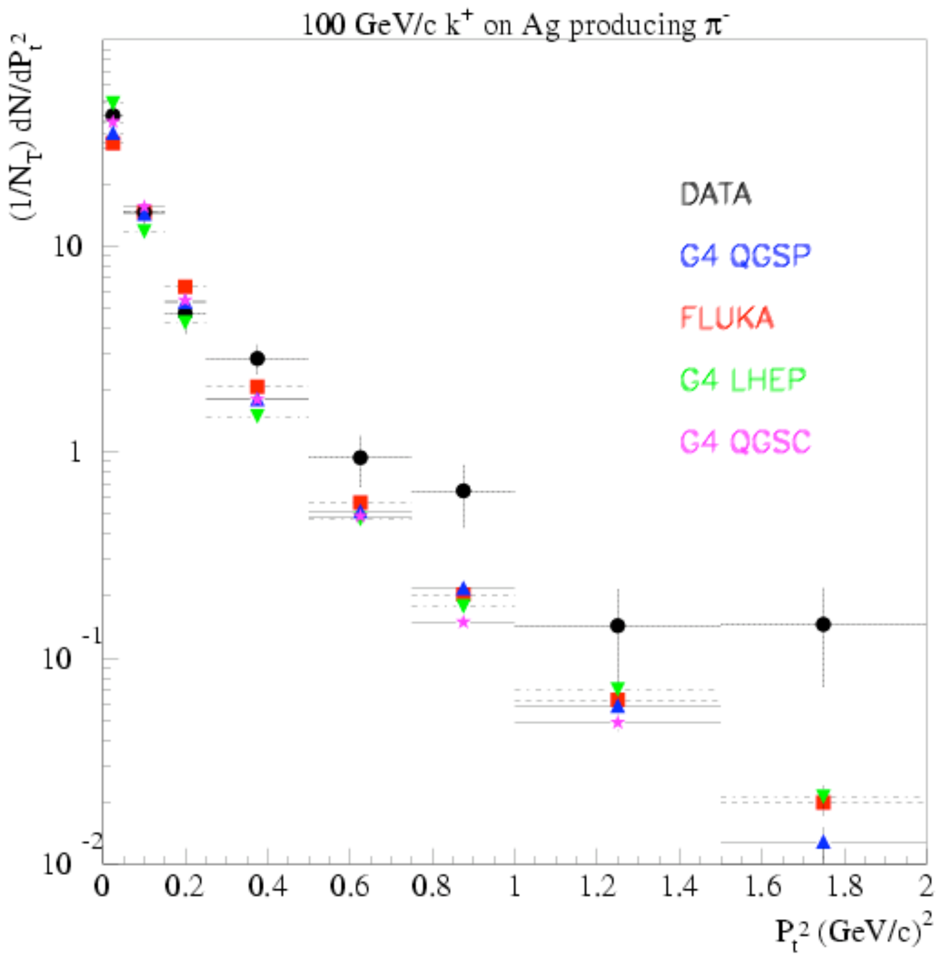
π^+ production by 100 GeV/c π^+ on Ag



π^- production by 100 GeV/c K^+ on Ag





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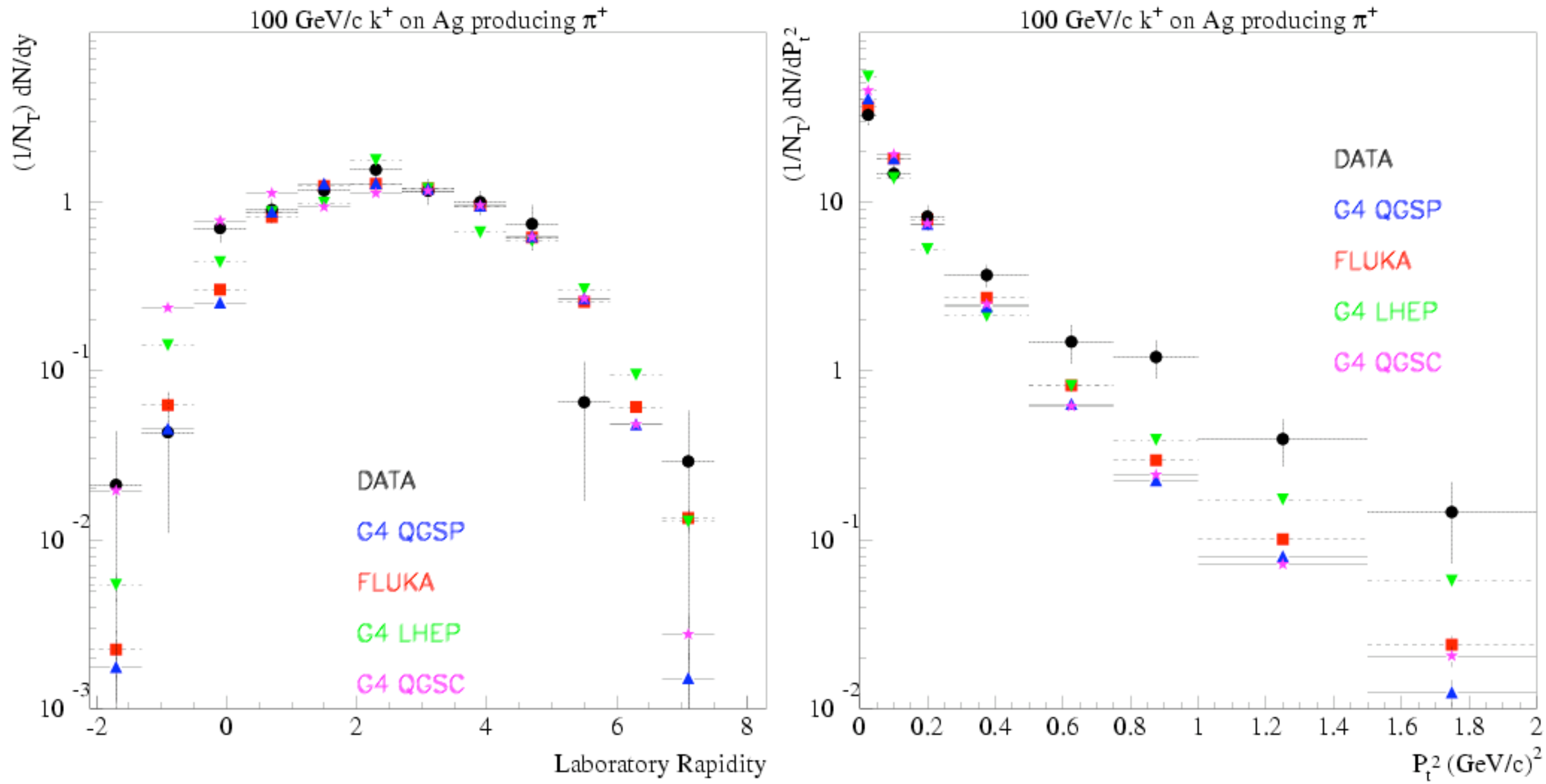
π^+ production by 100 GeV/c K^+ on Ag



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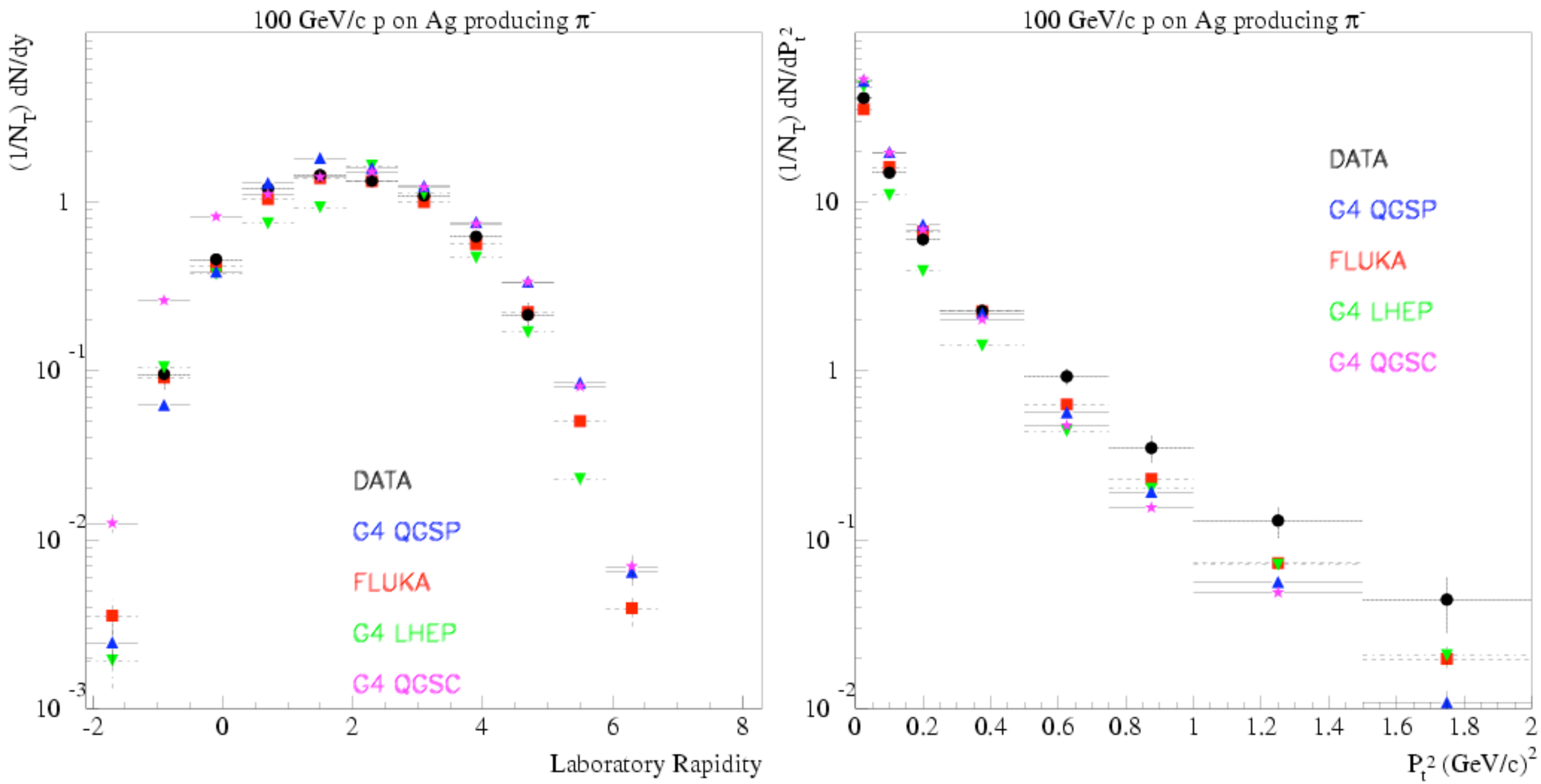
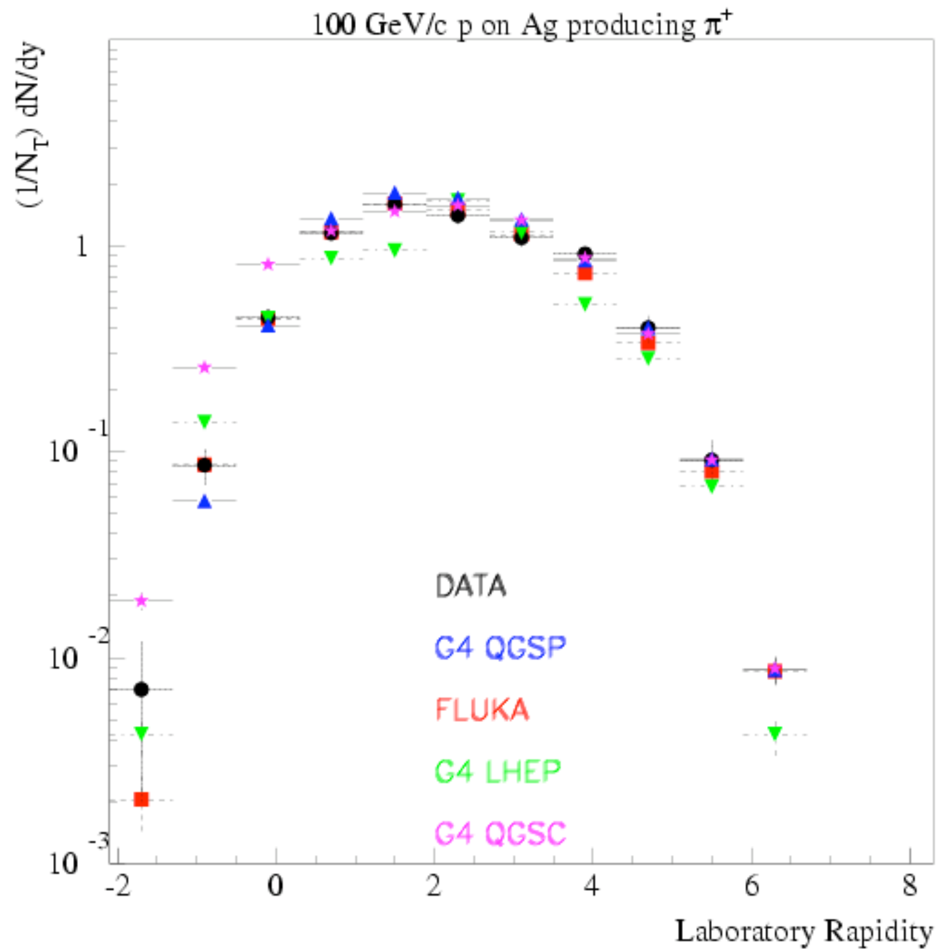
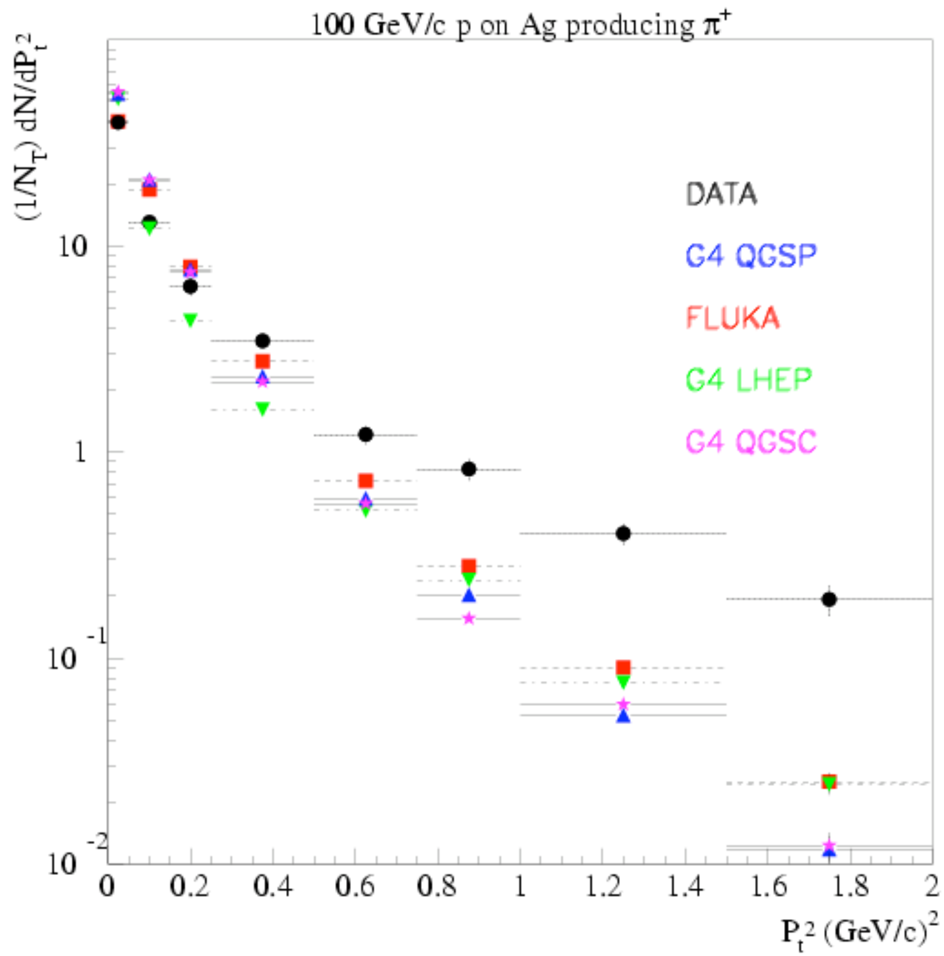
π^- production by 100 *GeV/c* **p** on **Ag**



π^+ production by 100 GeV/c p on Ag





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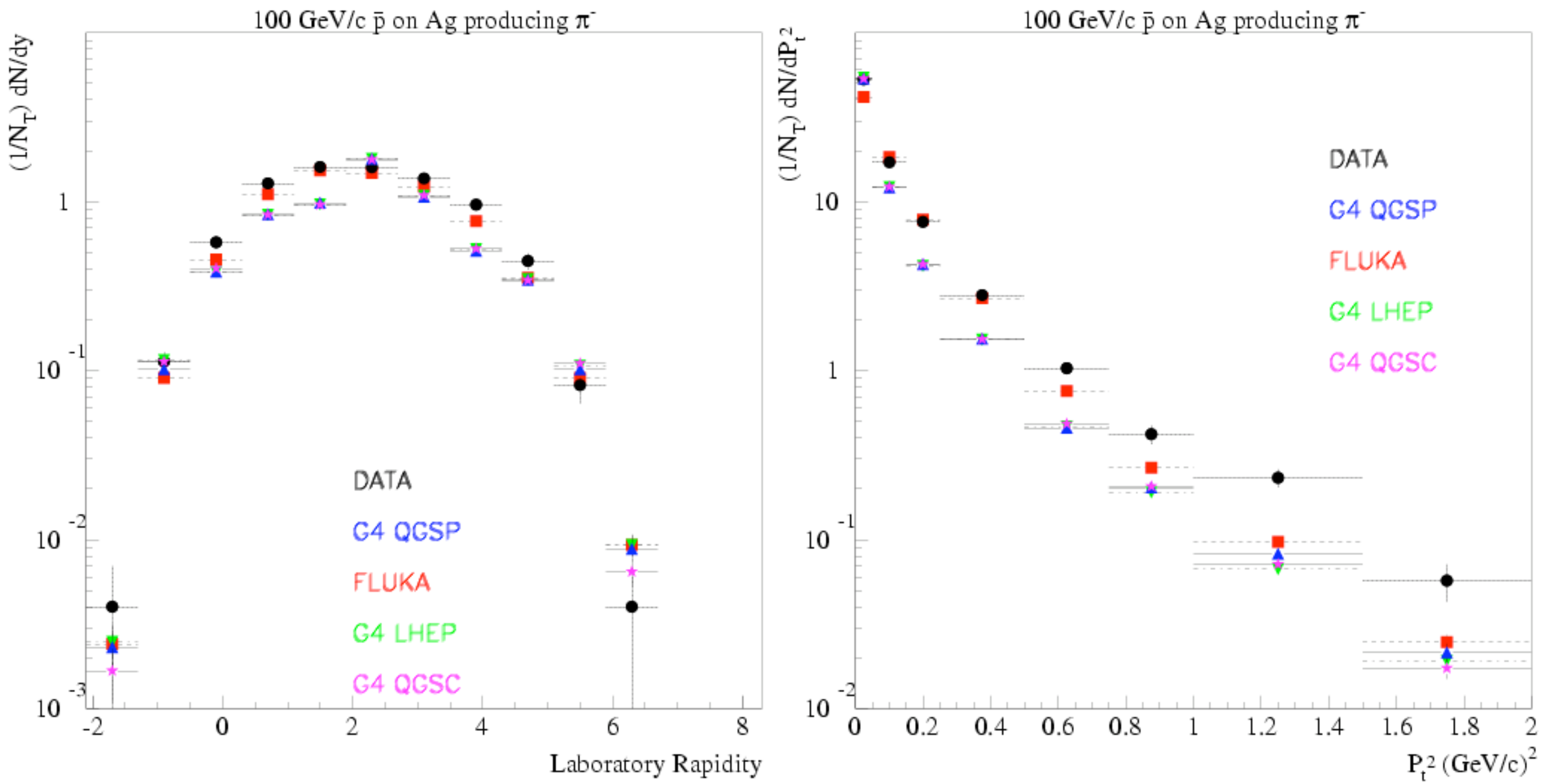
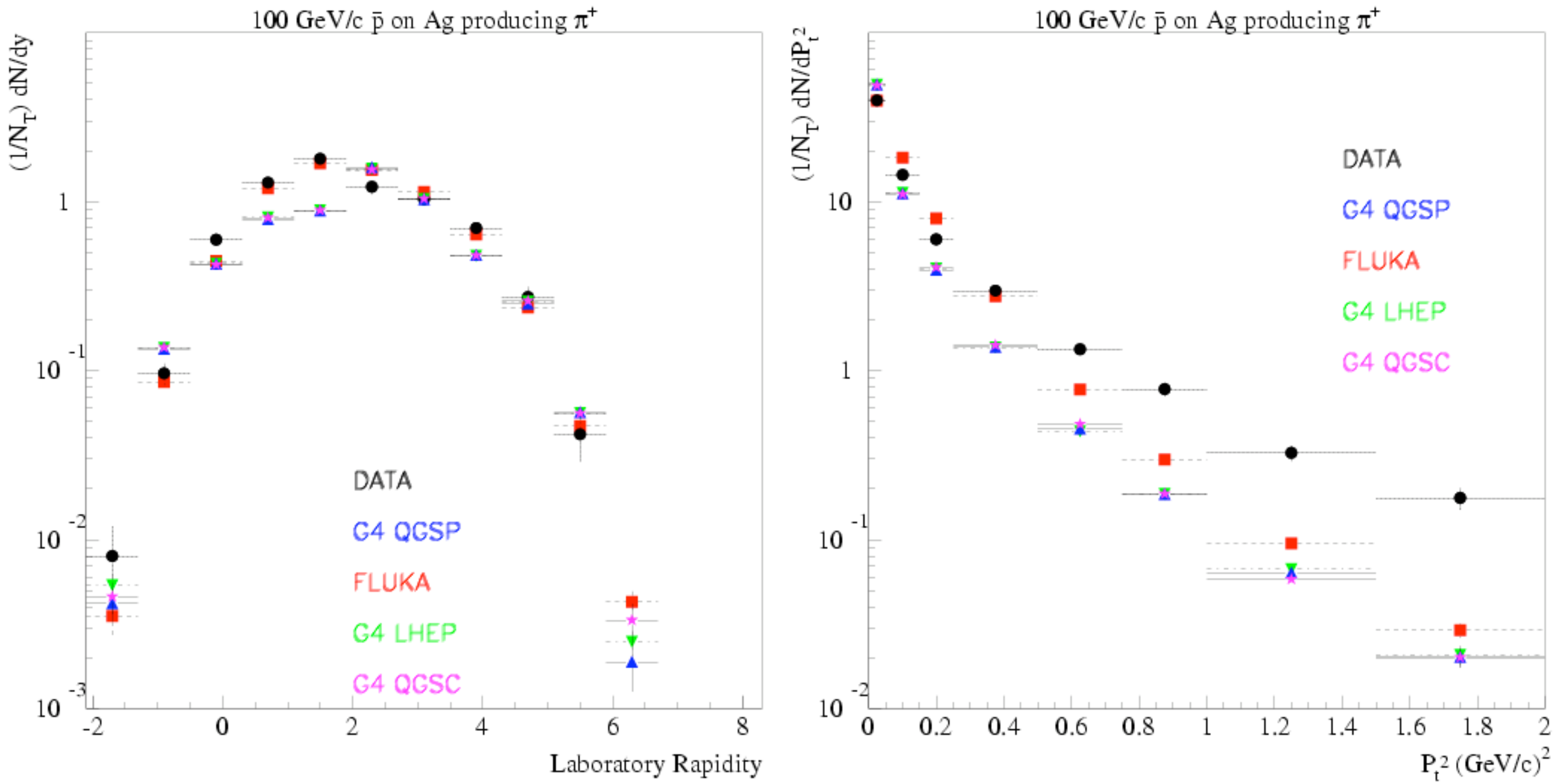
π^- production by 100 *GeV/c* p on Ag



π^+ production by 100 GeV/c p on Ag



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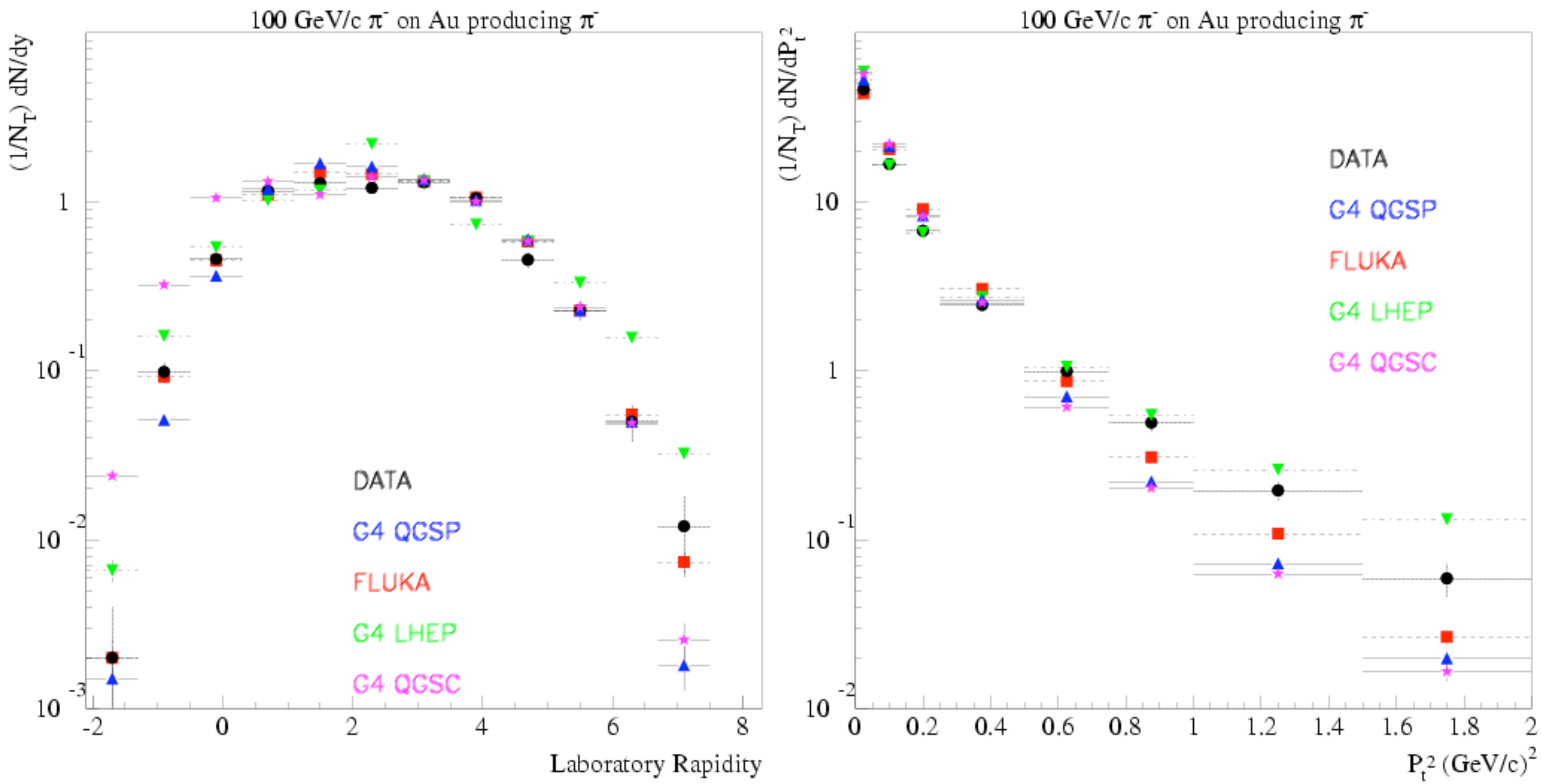
π^- production by 100 GeV/c π^- on Au



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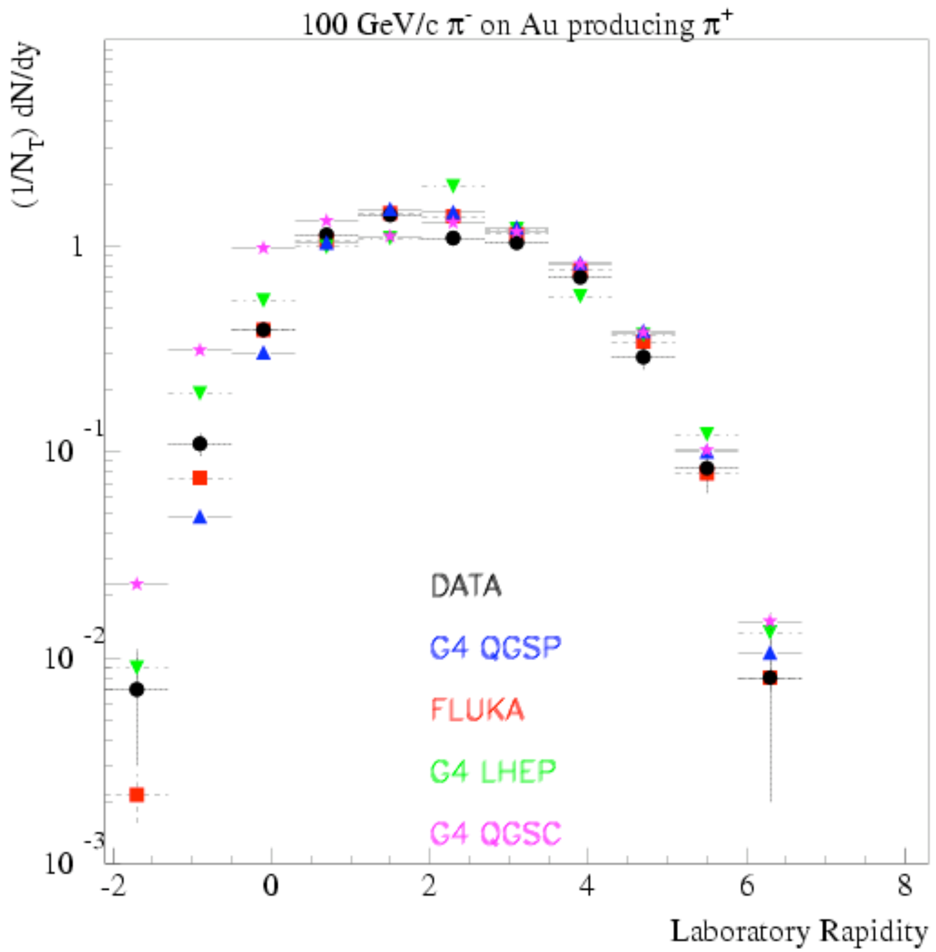
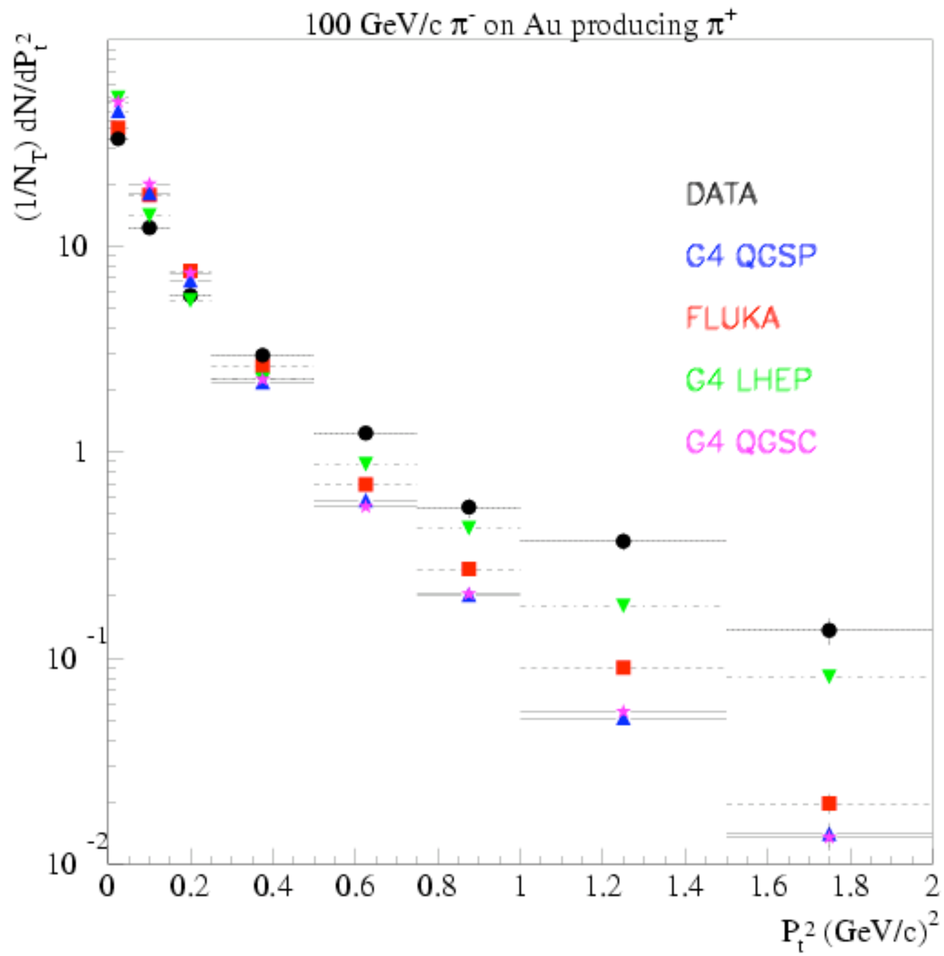
π^+ production by 100 GeV/c π^- on Au





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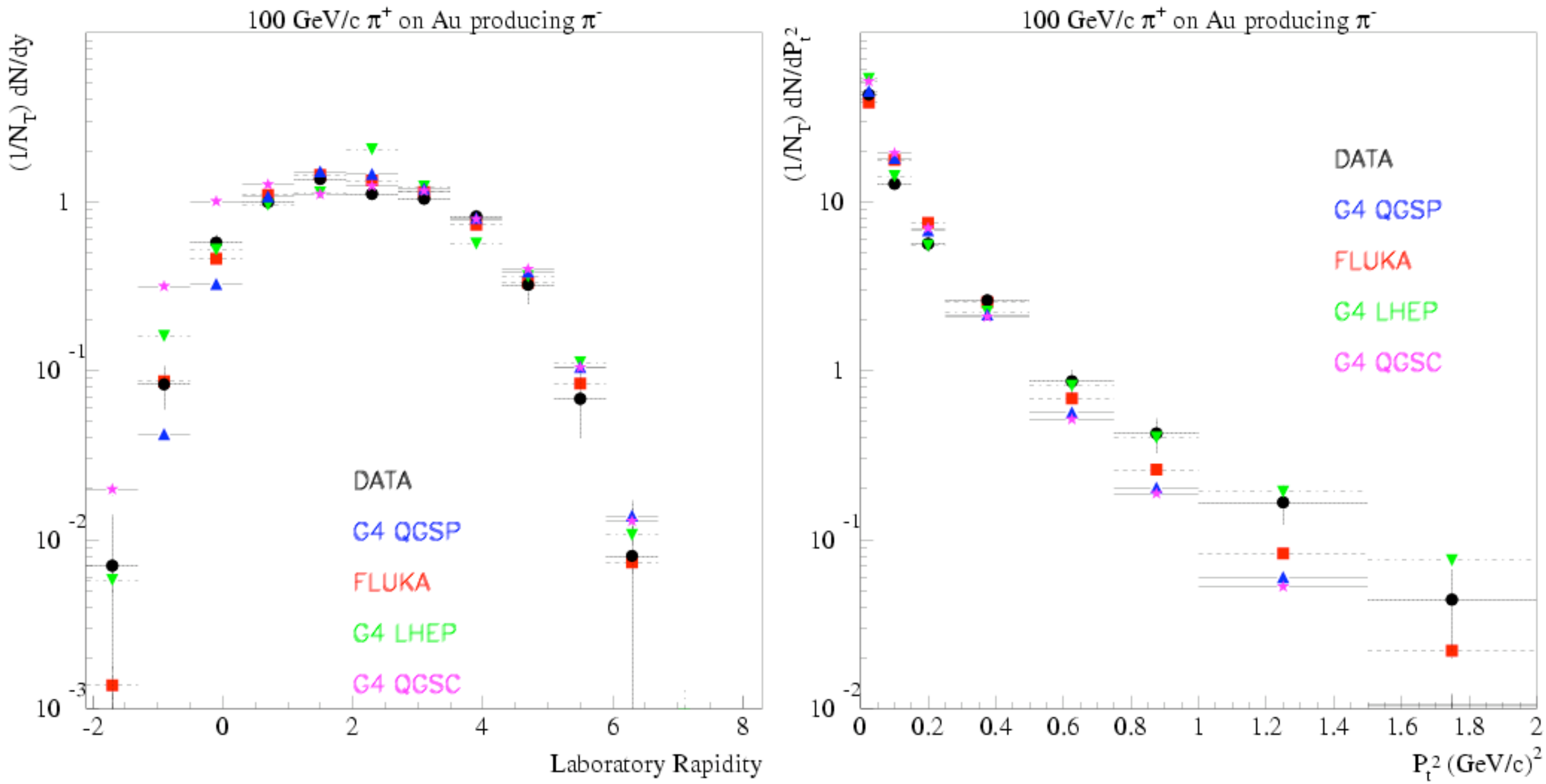
π^- production by 100 GeV/c π^+ on Au



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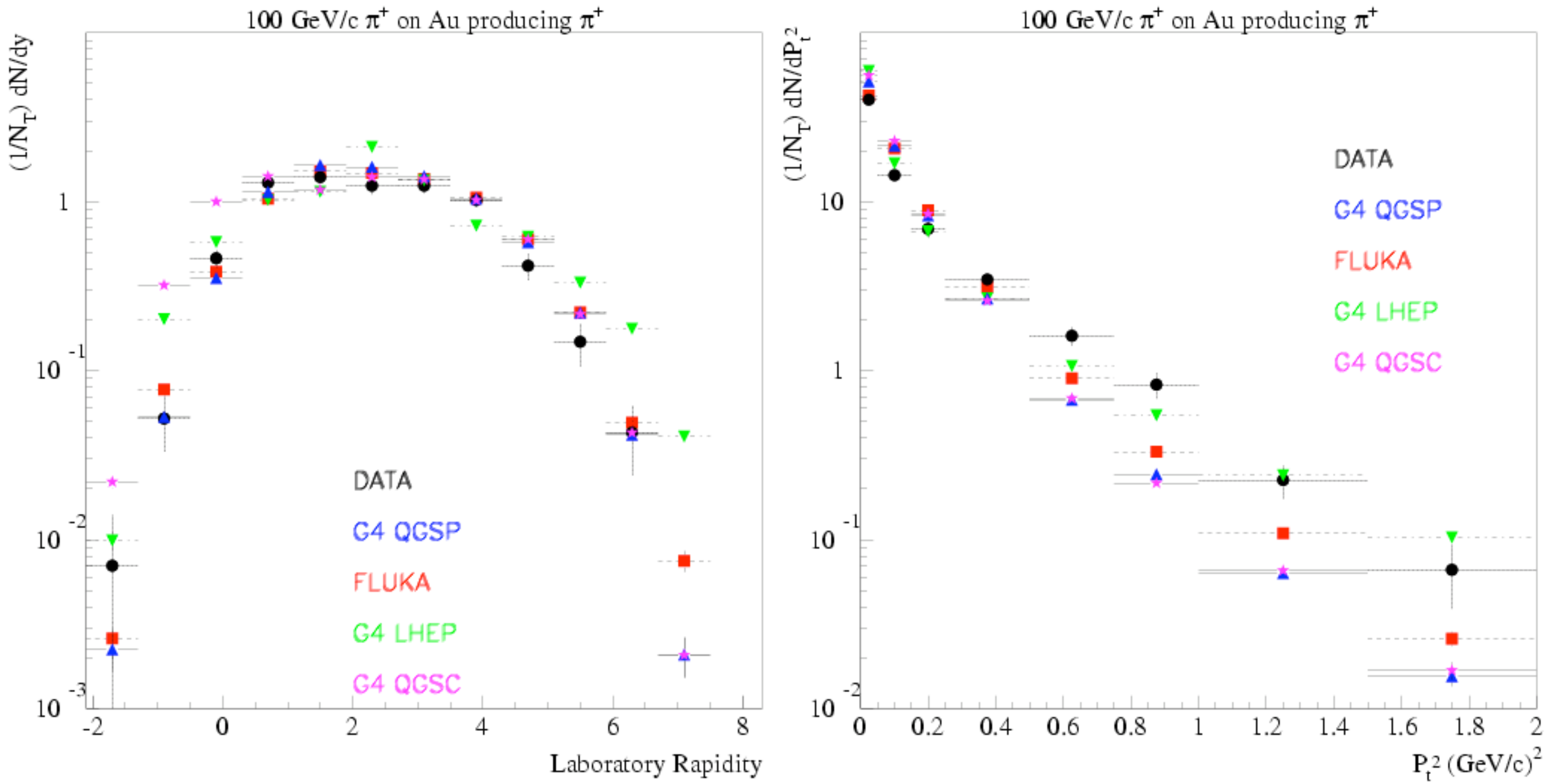
π^+ production by 100 GeV/c π^+ on Au



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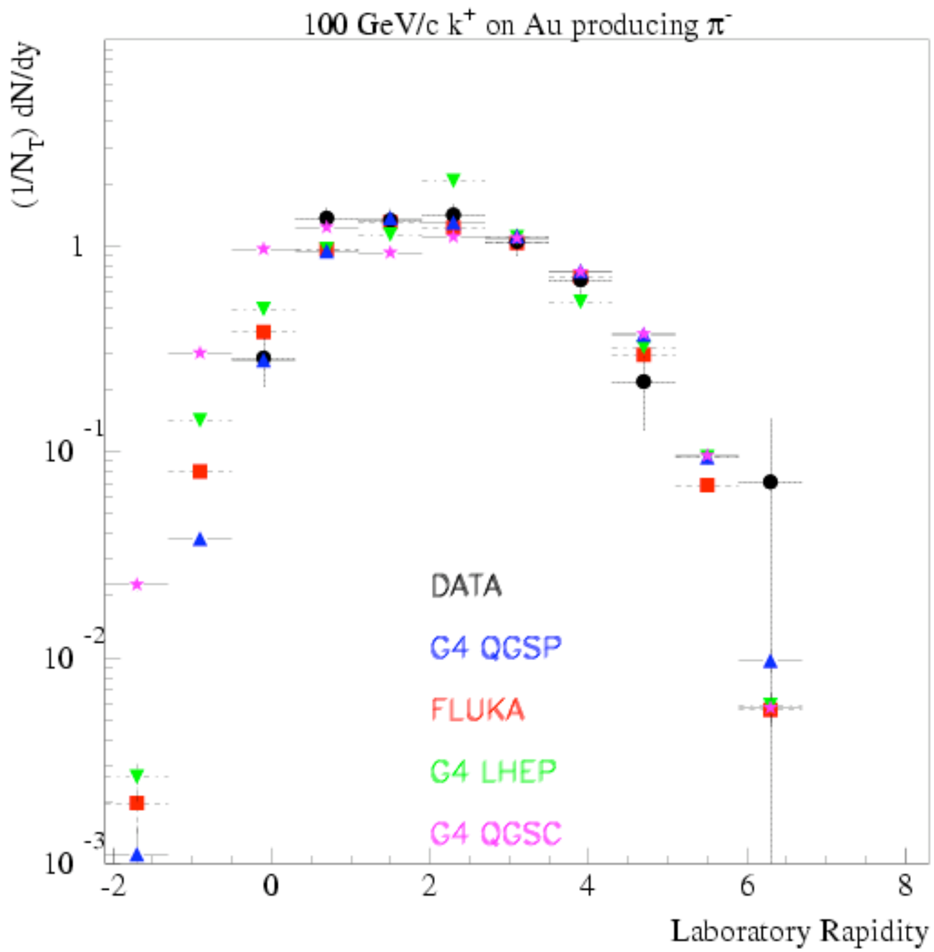
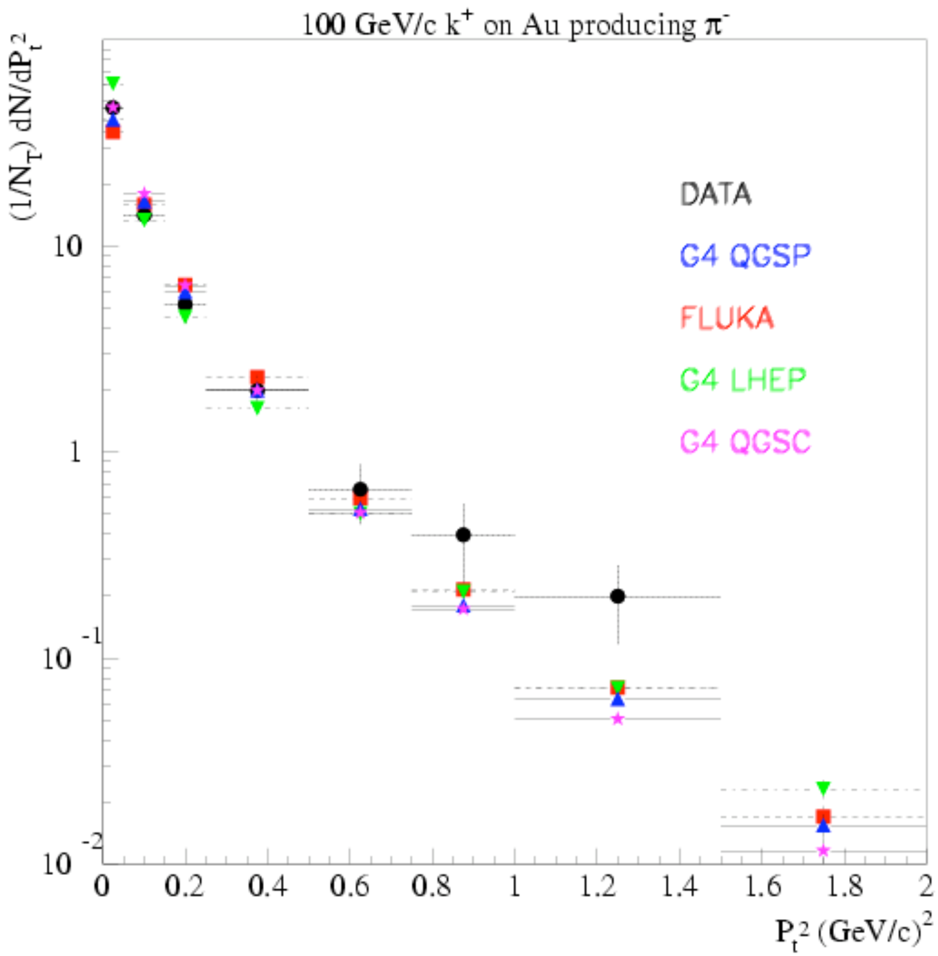
π^- production by 100 *GeV/c* K$^+$ on Au





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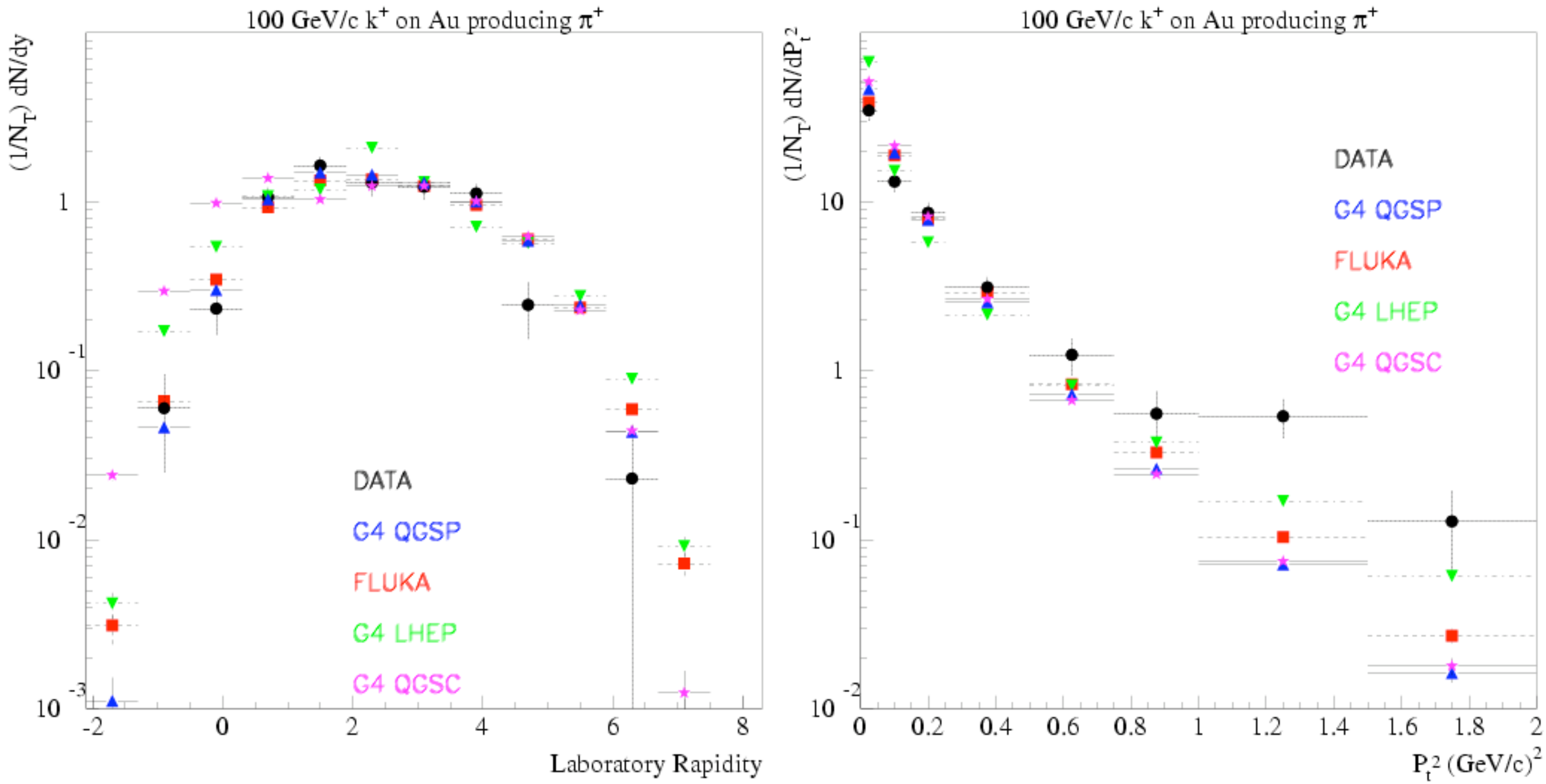
π^+ production by 100 *GeV/c* K$^+$ on **Au**



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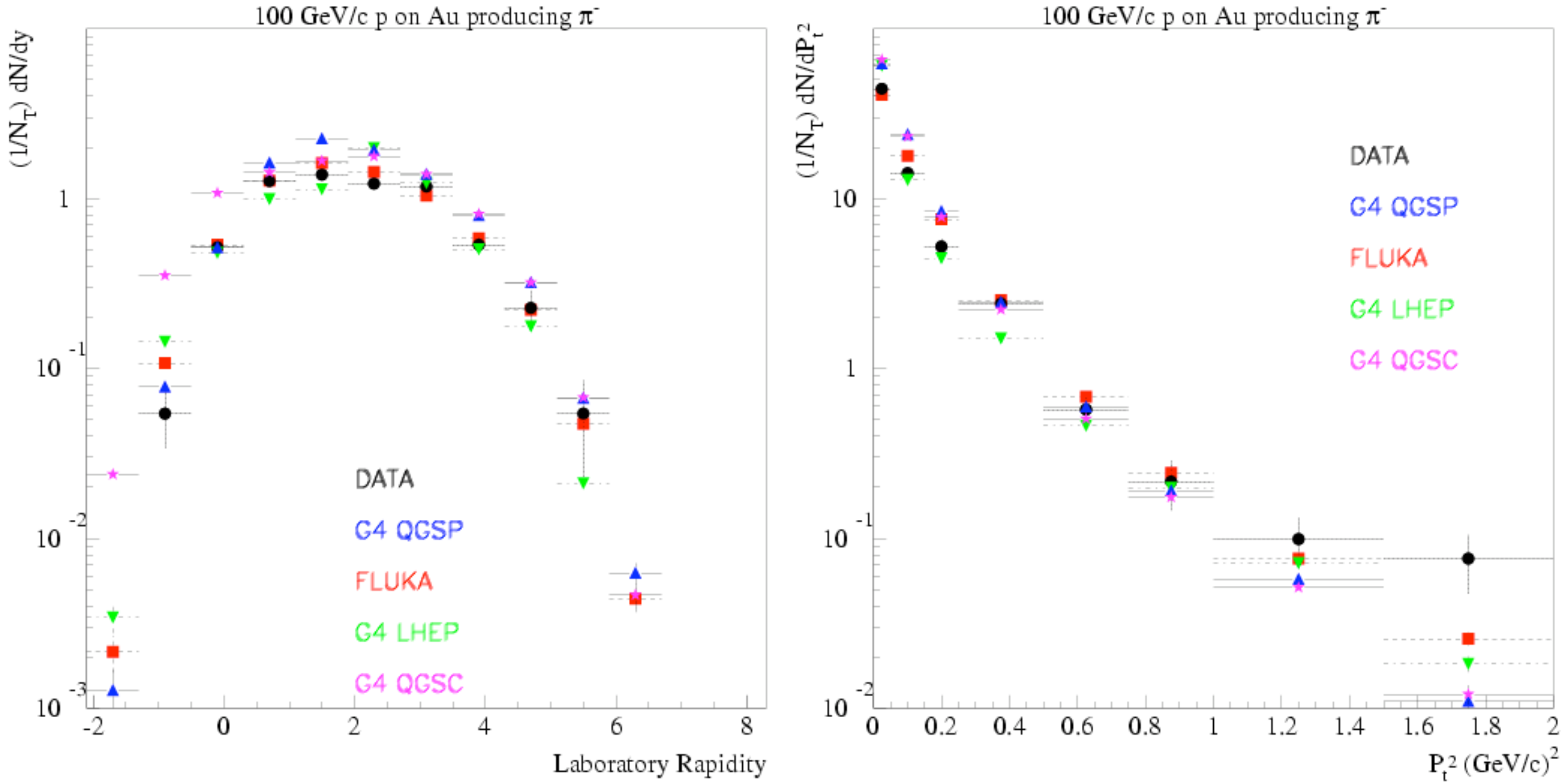
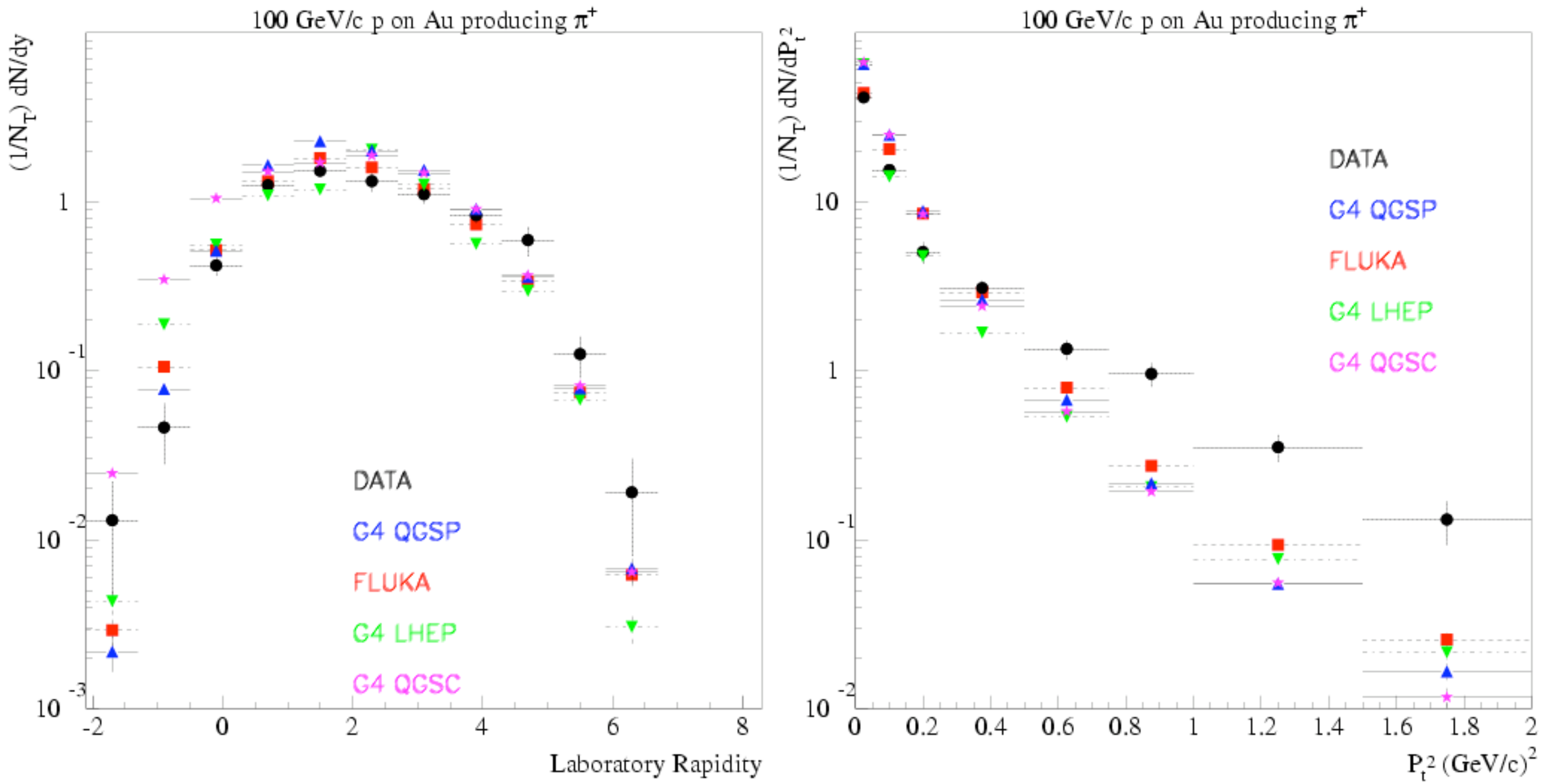
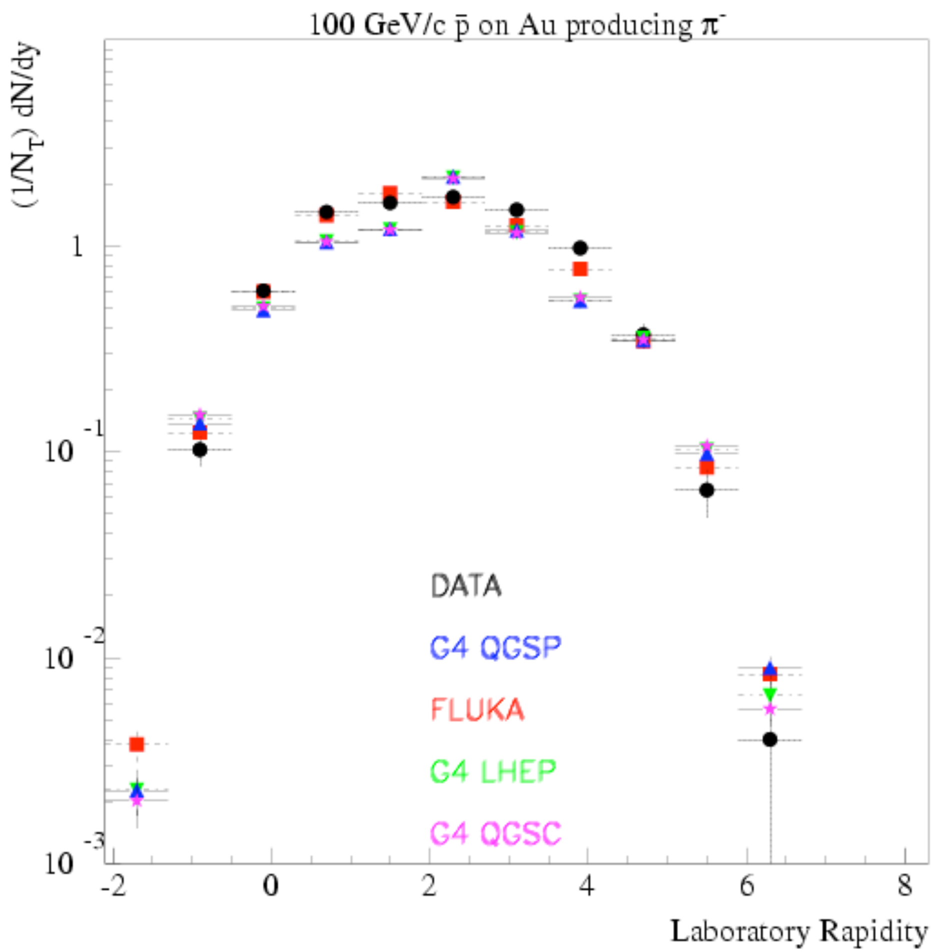
π^- production by 100 *GeV/c* **p** on **Au**

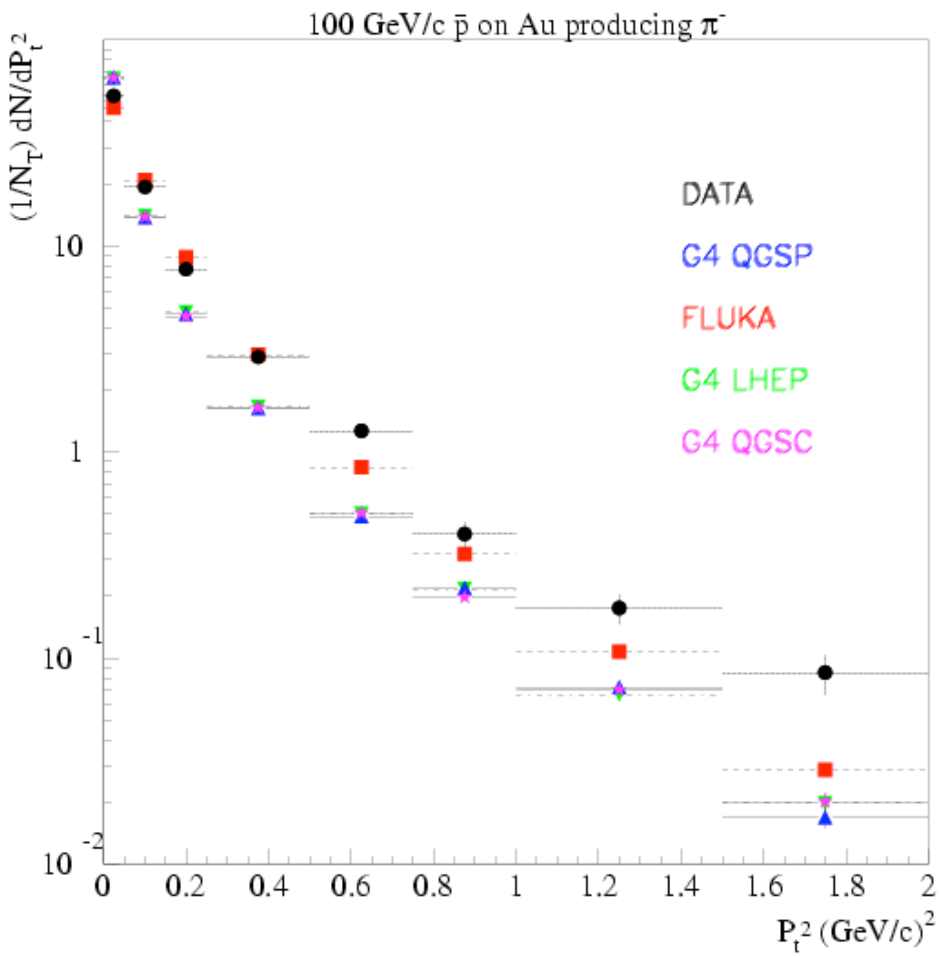


π^+ production by 100 *GeV/c* **p** on **Au**



π^- production by 100 *GeV/c* p on Au





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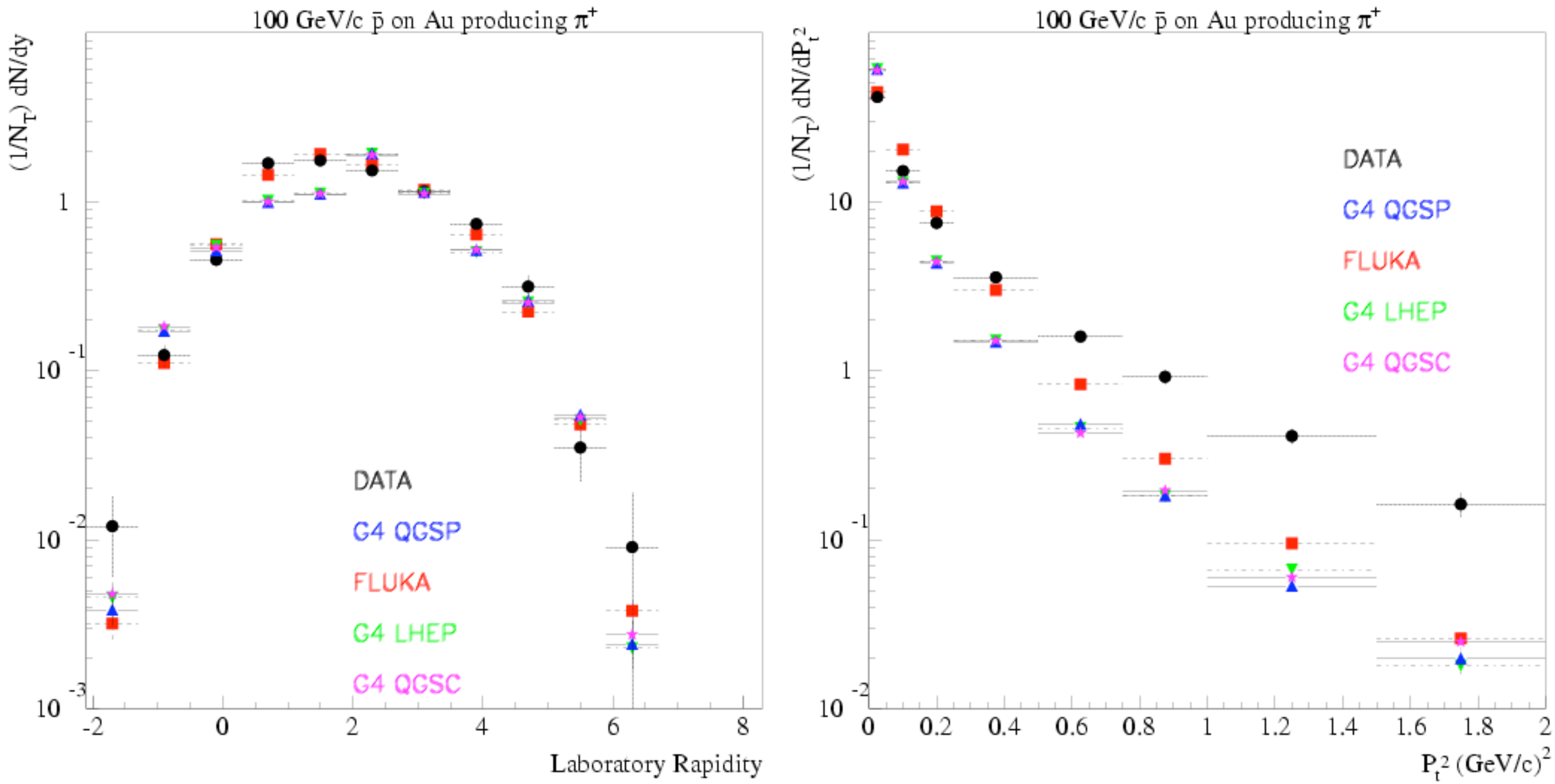
π^+ production by 100 *GeV/c* <u>p</u> on **Au**



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Conclusions

- Overall, Fluka, Geant4 QGSP, QGSC and LHEP simulations are in reasonable good agreement with most of the data.
  Fluka has more points of agreement.
- More in detail:
  - y distributions: G4 **QGSP**, **QGSC** and **Fluka** give a good description of the data; **LHEP** is less accurate.
  - P_T^2 distributions: G4 **LHEP** describes very well the data; **Fluka** is a bit narrower than data; G4 **QGSP** and **QGSC** are narrower still.