Kaon Production
Experiment & MC

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Motivation

What is the ambiguity of the K_L production yield?

1. In E391a study,
   – MC well reproduced data.
   – It doesn't depend on MC packages.
   ➔ We can rely on MC…

E391a

	K_L Yield per POT
Run-II data	$(1.36 \pm 0.08)\times10^{-7}$
GEANT3	$(1.32 \pm 0.03)\times10^{-7}$
GEANT4(QGSP)	$(1.31 \pm 0.11)\times10^{-7}$
GEANT4(QBBC)	$(1.54 \pm 0.12)\times10^{-7}$
FLUKA	$(1.40 \pm 0.02)\times10^{-7}$

Motivation

2. In E14 study,
   - Results varies with MC packages (FLUKA > 3 x G4)
     - Not resolved so far

➔ We're using G4/QGSP value as a default (conservative number)

E14

	K_L Yield per POT
GEANT3	$(3.8 \pm 0.1) \times 10^{-8}$
GEANT4(QGSP)	$(2.3 \pm 0.1) \times 10^{-8}$
GEANT4(QBBC)	$(2.7 \pm 0.3) \times 10^{-8}$
FLUKA	$(8.3 \pm 0.2) \times 10^{-8}$

Any kaon production data for the comparison ?

➔ Yes, there are some…

Reference

➔ BNL E802 experiment and comparison with MC

1. "Measurement of particle production in proton-induced reactions at **<u>14.6 GeV/c</u>**"
   PRD 45 (1992) 3906-3920

2. "Comparison of inclusive particle production in 14.6 GeV/c proton-nucleus collisions with simulation"
   NIM B246 (2006) 309-321

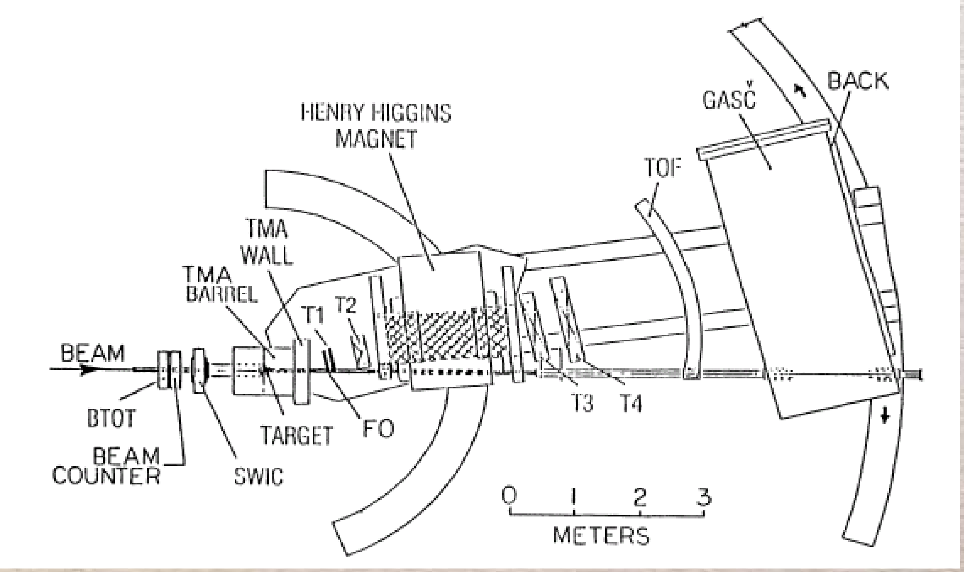
BNL E802 (ref.1)

- Primary momentum = 14.6 GeV/c
- Target = Be, Al, Cu, Au
- Production angle = 5 to 58 degree
- Momentum of products measured by a spectrometer
- Particle ID by TOF
  and Gas Cerenkov

pion : upto 5 GeV/c

kaon : upto 3.5 GeV/c

proton : upto 8 GeV/c



To compare with E14 / E391a

- Target material
  - Ni (Z=28,A=59) target in case of E14
    → Looking at Cu (Z=29,A=64) data
  - Pt (Z=78,A=195) target in case of E391a
    → Looking at Au (Z=79,A=197) data

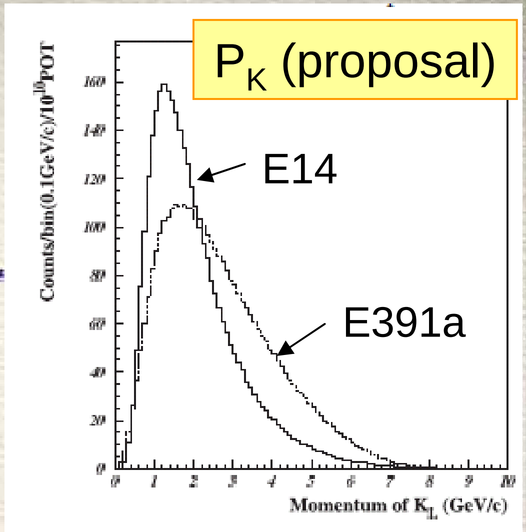
- Parameters used in E802
  - Transverse kinetic energy : m_t-m_0
  - Rapidity : y

$$m_t - m_0 = \sqrt{m_0^2 + p_T^2} - m_0$$

$$y = \frac{1}{2}\ln(\frac{E+P_L}{E-P_L})$$

$$\frac{d^3\mathbf{p}}{E} = 2\pi \cdot m_t dm_t dy$$

E14 / E391a case



- Region of interest for m_t, y
  - E14 : P_K peak=1.3GeV/c, av.=2.1GeV/c
  - E391a : P_K peak=1.8GeV/c, av.=2.6GeV/c

P_K (GeV/c)	16 degree (E14 step1) *				4 degree (E391a)			
	P_L	P_T	m_t-m_0	y	P_L	P_T	m_t-m_0	y
1.0	0.96	0.28	7.2e-2	1.3	1.00	0.07	4.9e-3	1.4
1.5	1.44	0.41	**0.15**	**1.5**	1.50	0.11	0.01	1.8
2.0	1.92	0.55	**0.25**	**1.7**	2.00	0.14	**0.02**	**2.1**
2.5	2.40	0.69	0.35	1.8	2.49	0.17	**0.03**	**2.3**
3.0	2.88	0.83	0.47	1.8	2.99	0.21	0.04	2.4

(*) In reality, a scaling factor should be considered P(proton)=14.6 → 30 GeV/c.
m_t-m_0 $P_T^2/2m_K$(P_T<<m_K) or P_T(PT>>m_K), $P_T \propto s^{1/2} \propto E^{1/2}$ → approx. $E^{1/2}$~E, *i.e.*, 1.4~2?

E14 : Step1 / Step2 cases

- Region of interest for m_t, y
  - Step1 (16 deg.) : P_K ~ 2 GeV/c
  - Step2 (5 deg.) : P_K ~ 5 GeV/c ← smaller angle, higher momentum

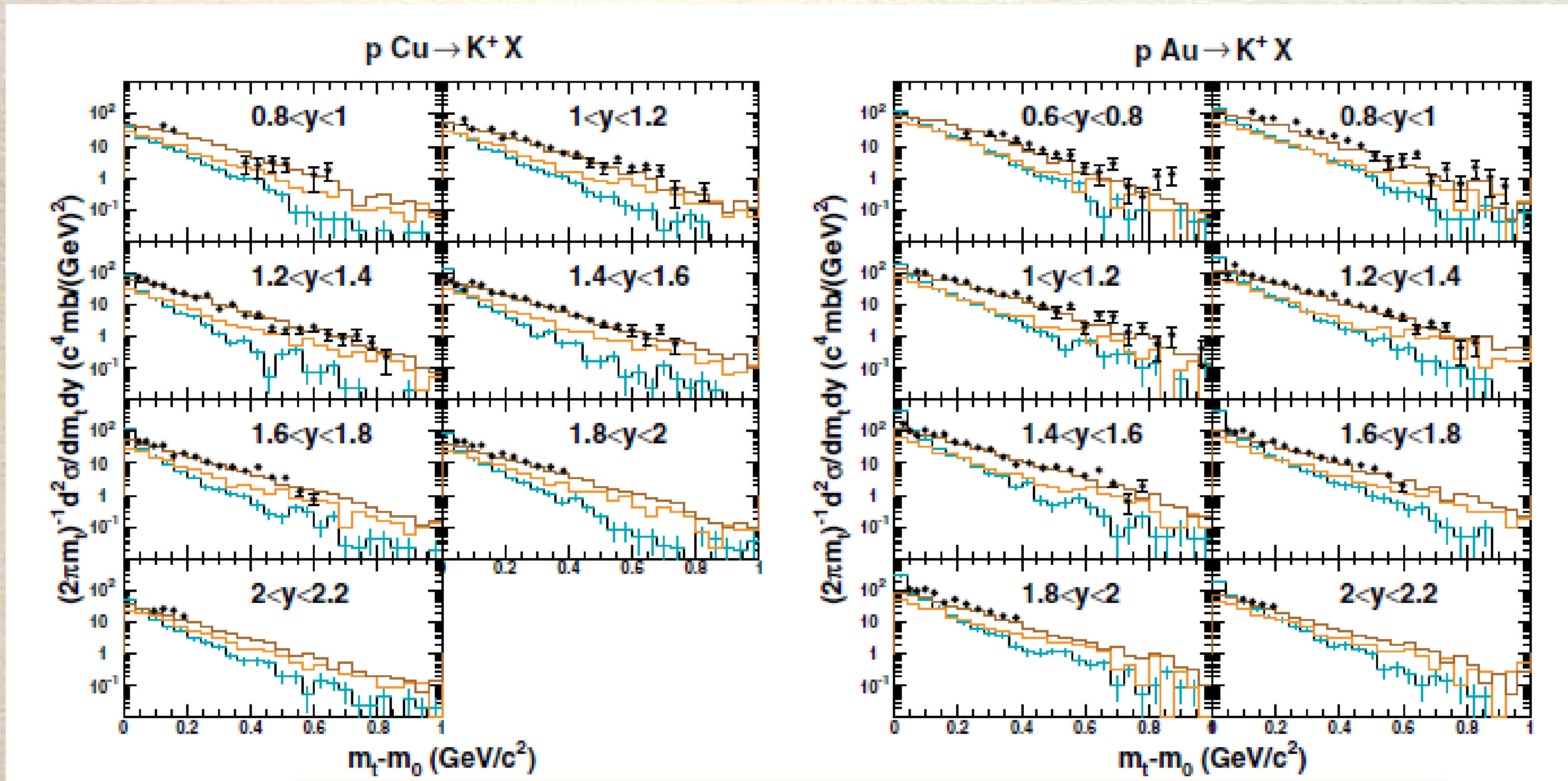
P_K (GeV/c)	16 degree (E14 step1)			
	P_L	P_T	m_t-m_0	y
1.0	0.96	0.28	7.2e-2	1.3
1.5	1.44	0.41	0.15	1.5
2.0	1.92	0.55	**0.25**	**1.7**
2.5	2.40	0.69	0.35	1.8
3.0	2.88	0.83	0.47	1.8

P_K (GeV/c)	5 degree (E14 step2)			
	P_L	P_T	m_t-m_0	y
2.0	1.99	0.17	0.03	2.0
3.0	2.99	0.26	0.06	2.4
4.0	3.98	0.35	0.11	2.6
5.0	4.98	0.44	**0.16**	**2.7**
6.0	5.98	0.52	0.23	2.8

In both cases, the m_t-m_0 value becomes around 0.2 at the peak momentum.

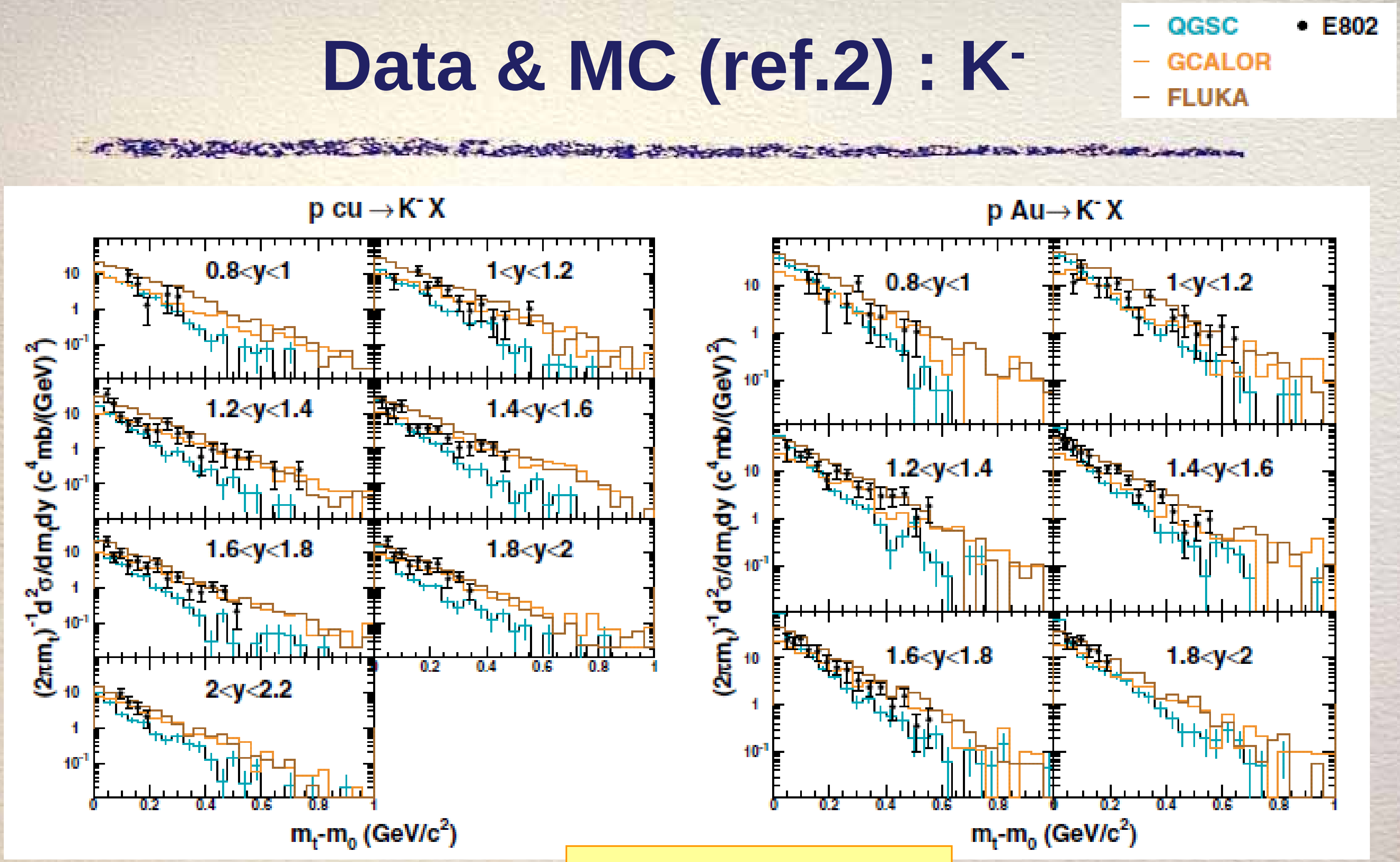
Data and MC (ref.2) : K^+

- QGSC
- GCALOR
- FLUKA
- • E802



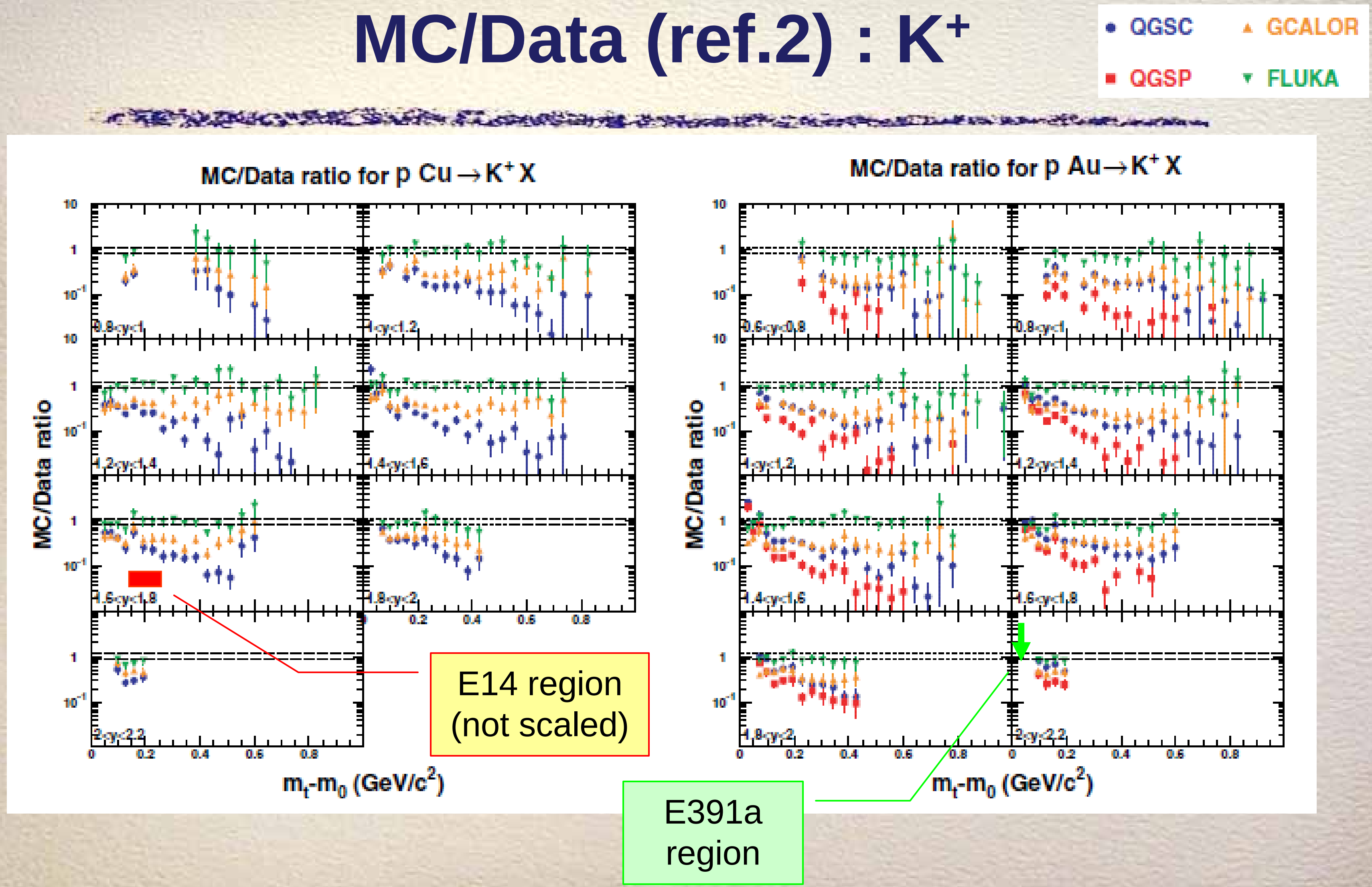
- [better] FLUKA -- G3(GCALOR) -- G4(QGSC) [worse]
- Especially, Exponential shape not reproduced except FLUKA

Data & MC (ref.2) : K^-

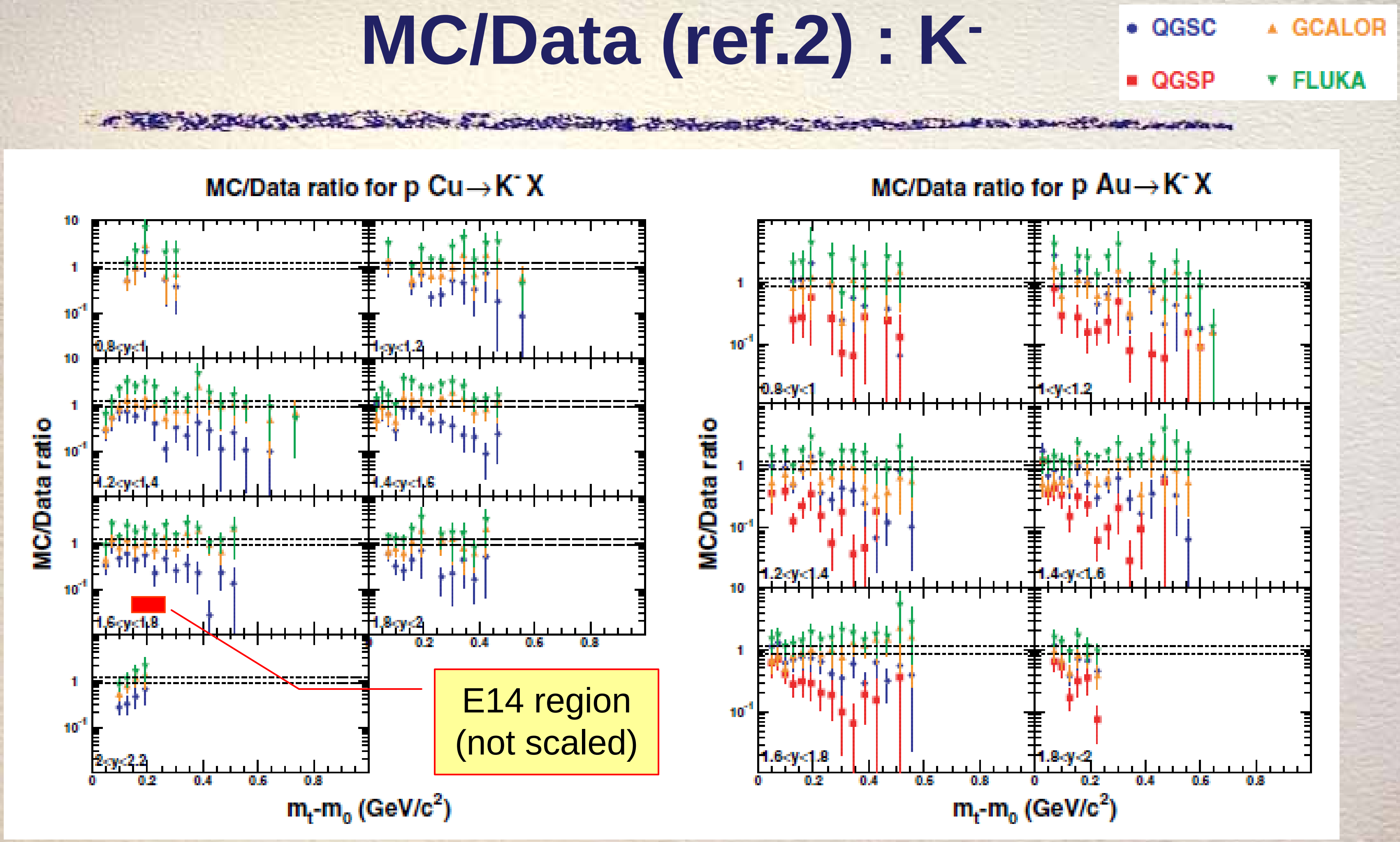


Similar tendency to K^+

MC/Data (ref.2) : K^+



MC/Data (ref.2) : K^-



Summary

- What we learned from BNL E802 & MC (K^+ / K^-)
  - FLUKA seems the best estimator for Kaon yield.
  - G4(QGSC) cannot reproduce the slope in m_t dependence.
    - E391a: m_t-m_0 ~ 0.02 → G4(QGSC) ~ FLUKA ~ E802 Data
    - E14: m_t-m_0 ~ 0.2 → G4(QGSC) < FLUKA ~ E802 Data
G4 (1/2-1/3) FLUKA (though hard to read…)
  - Discrepancies depend on m_t-m_0 value
    - Larger production angle → larger discrepancy
    - Larger peak momentum → larger discrepancy

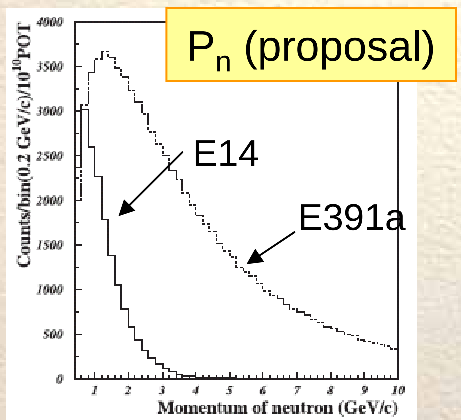
- Beam survey for E14 will provide new data point on kaon production (Planned in Autumn in 2009)

How about neutron?

Looking at proton data in E802…

P~1GeV/c、16 degree production

→ m_t-m_0=0.04、y=0.87



- FLUKA ~ E802 Data
- <u>G4(QGSC) ~ 1/2 FLUKA</u>

➔ 2 times more neutrons

E14 region (not scaled)