Cross sections and multiplicities studies in LHCb

S. Miglioranzi(CERN), G. Corti(CERN),
D. Pinna (Cagliari University)

07/07/2010

Introduction

For LHCb is vital to have multiplicities reproduced and right cross sections implemented in the simulation.

Need to understand the material interaction contribution (systematic) to the asymmetries observed in latest studies of p/pbar, Λ/Λbar, K+/K-

- Cross-check the interaction cross sections simulated inside Geant4 for p, K, pi using different targets:
  - interaction probability from xsec of LHEP provided by Geant4 authors
  - interaction probability from available data (COMPAS database)
  - interaction probability using a simplified geometry in the LHCb framework
- Check how the interaction cross sections vary using different PLs (LHEP, QGSP_BERT, FTFP_BERT)

- Using PGUNs and MinBias we check how the multiplicities in hadronic interactions vary using different PLs

..bit of history

- Oct. 09: Catania G4 Workshop, the statement was:

  - $\sigma_{\pi N}$ (LHEP): GEISHA cross-section
  - $\sigma_{\pi N}$ (OTHERS): Barashenkov cross-section data
  - σ_{KN} : GEISHA cross-section from πN with scaling factor
    probably non optimal
  - σ_{pN}(LHEP): GEISHA cross-section data
  - σ_{pN} (OTHERS): Wellish-Axen cross-section

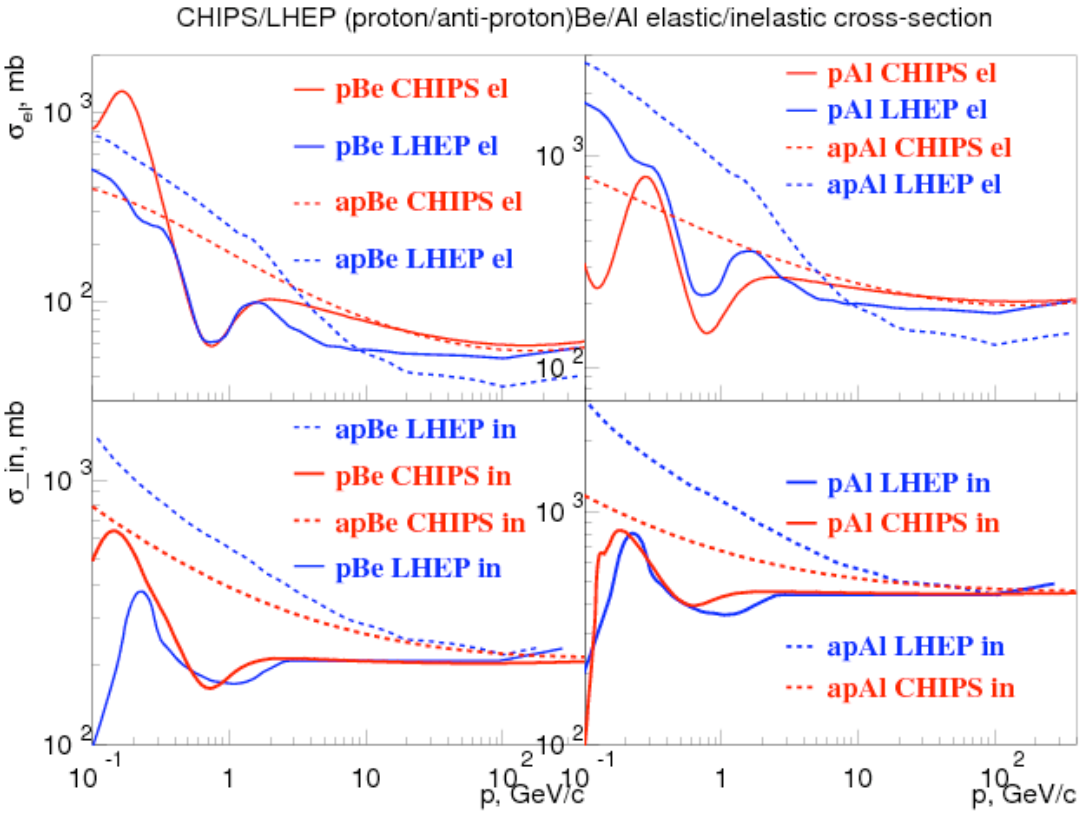
- Feb. 10: LHCb Software week, the statement was:

  - The K+ -A and K- A inelastic cross-sections
    - for all Physics Lists are inherited from GEISHA and are quite poor, e.g. σ (K+ A) = σ (K- A)
    - CHIPS has separate ones

Need to clarify what exactly was inside our Geant4 setting (LHEP used sofar)

p(pbar) on Be/Al - M. Kosov (Geant4)

Full set of LHEP cross sections for different particle types from Mikhail (see backup)

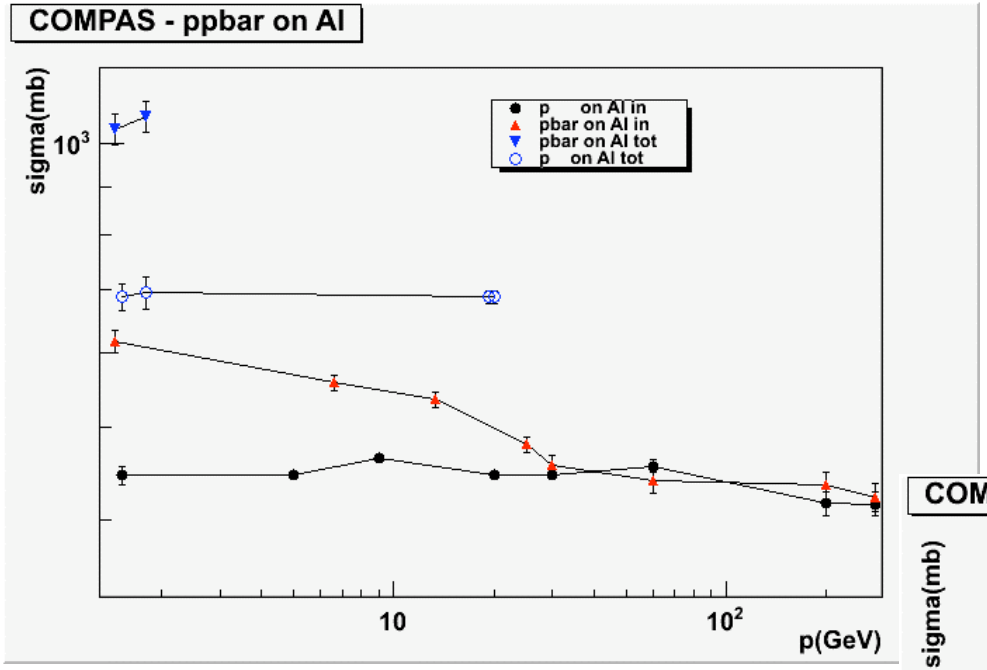


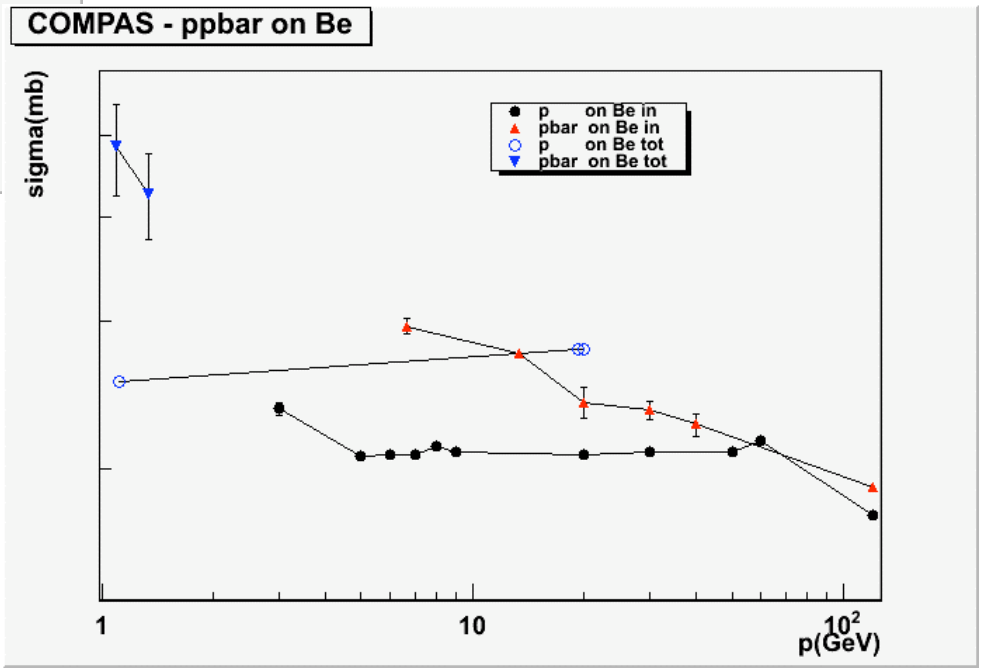
LHEP known problems:

- Systematic differences between p/ap cross sections at high energies. They should not exist.
- The K+ inelastic cross section does not drop to zero for zero energy (it should).
- At high energies the LHEP fit both for elastic and inelastic cross section should give the same results for K+ and K-, but it does not.
- pi+/pi- elastic cross sections are the same (should be different at low energies). True for all Phys. Lists.

COMPAS database - p(pbar) on Al/Be

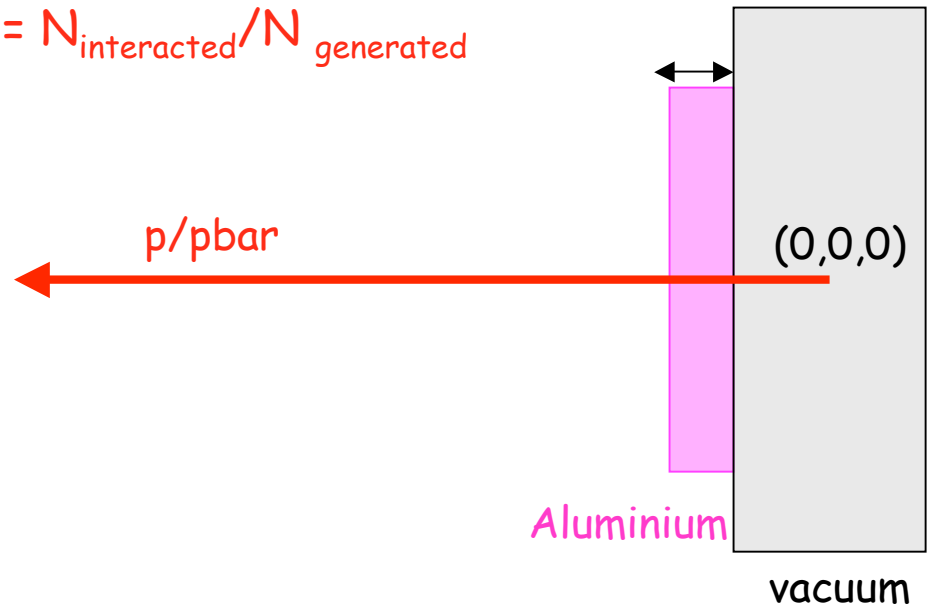
Measurements found in: http://wwwppds.ihep.su:8001/ppds.html





Exercise inside the LHCb framework

- Geant4 9.2p3 used
- simplified geometry simulated (Vacuum box + Aluminium box)
- No δ-rays simulation (to avoid counting artifice)
- setup PGUNs originating from (x,y,z)= (0,0,0), theta_min = 0.0 rad, theta_max=0.0 rad
- PGUN Momentum = 1GeV, 5GeV, 10GeV, 13GeV, 100GeV considered
- PGUN originating in the middle of Vacuum box
- Different thicknesses of the Aluminium box have been checked (1mm, 1cm, 5cm and 10 cm ->breakdown observed) for consistency
- Interaction probability = $N_{interacted}/N_{generated}$

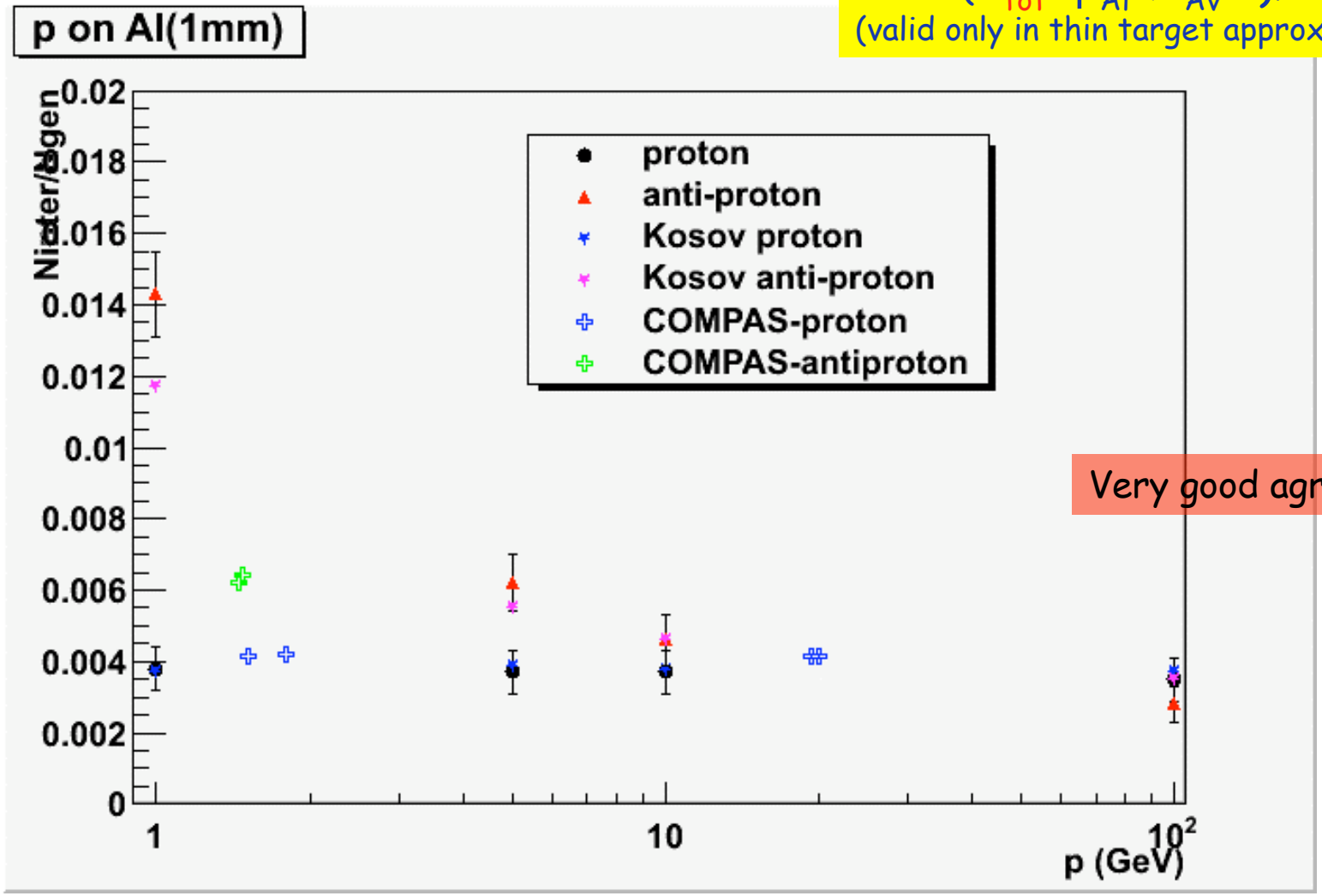


p (pbar) on Al (1mm)

Kosov's xsecs and COMPAS measurements converted into interaction probability with:

Pint = $(\sigma_{tot}\ \rho_{Al}\ N_{Av}\ x)/A$

(valid only in thin target approx)



Very good agreement found

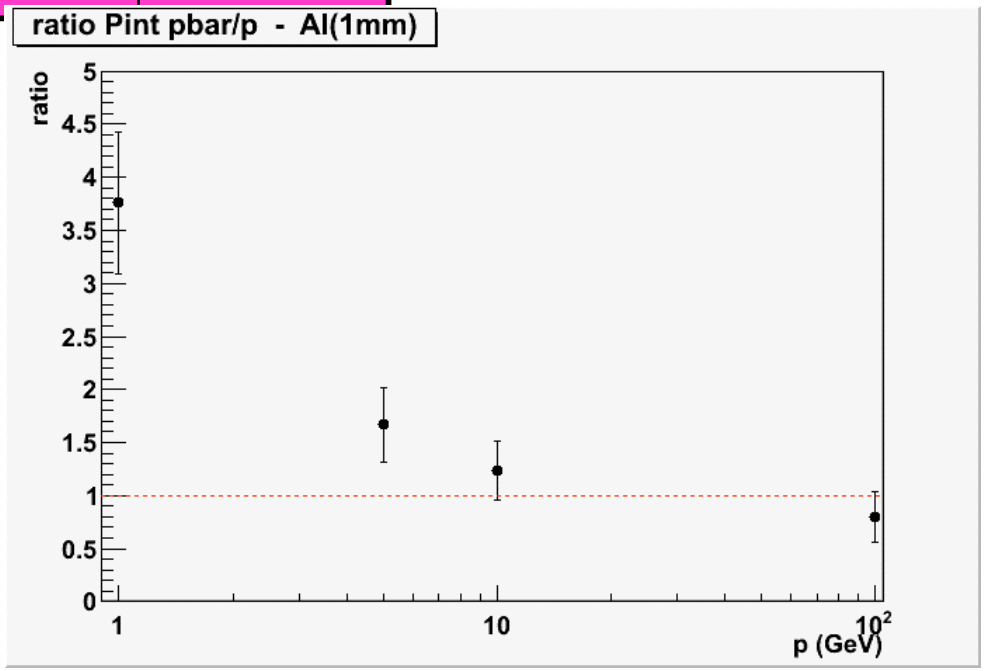
p (pbar) on Al (1mm)

- Ngenerated = 10K (1 p per event)

PGUN	P (GeV/c)	Nint/Ngen	Err	Ratio pbar/p
p	1.	0.0038	0.0006	3.76±0.67
pbar	1.	0.0143	0.0012	
p	5.	0.0037	0.0006	1.67±0.35
pbar	5.	0.0062	0.0008	
p	10.	0.0037	0.0006	1.24±0.28
pbar	10.	0.0046	0.0007	
p	100.	0.0035	0.0006	0.8±0.24
pbar	100.	0.0028	0.0007	

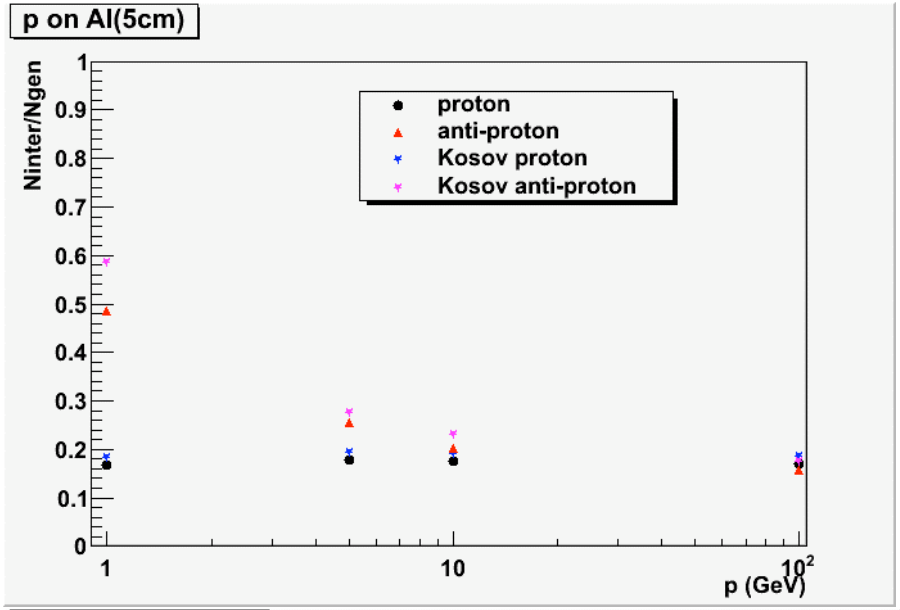
PDG numbers for targets being p, n or d

P (GeV/c)	Ratio pbar/p	PDG range Ratio pbar/p
1.	3.76±0.67	3.4 - 4.2
10.	1.24±0.28	1.2 - 1.4
100.	0.8±0.24	1. - 1.1



p(pbar) on Al,Be,Si(5cm) - 10K pguns

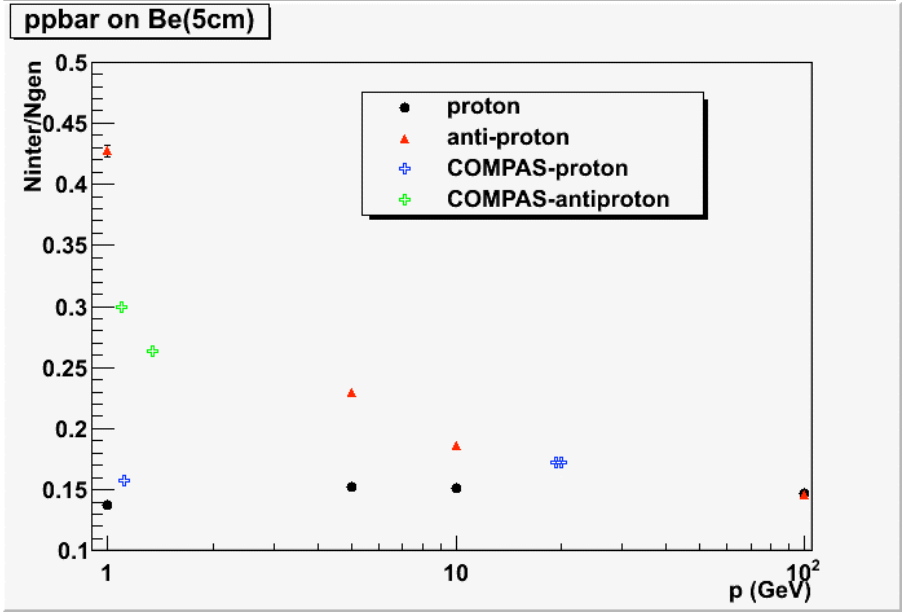
Tests were done considering materials used in beam pipe and trackers - Al, Be, Si...

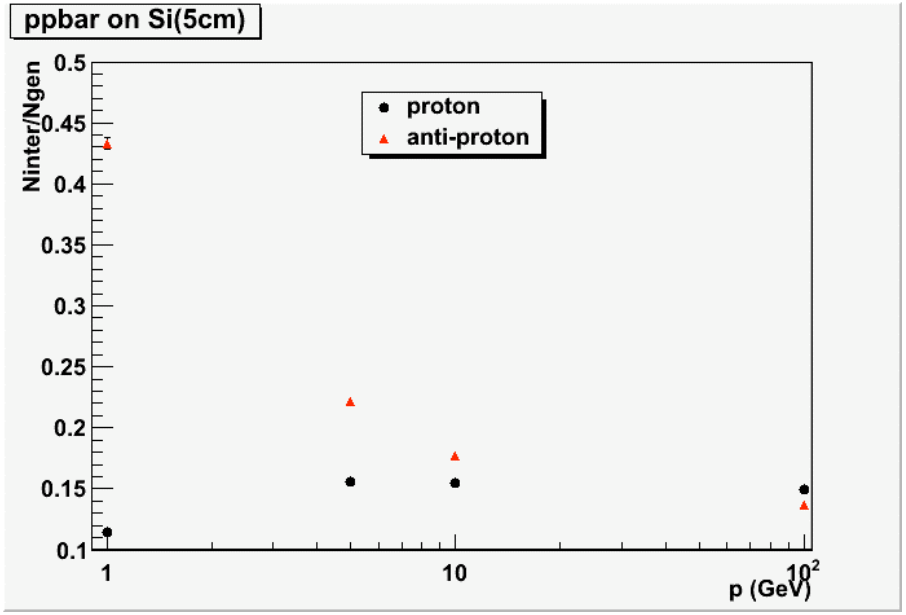


Aluminium radiation length = 89mm

LHCb detector material budget (up to RICH2) ~0.6 X_0

-> Al thickness of 53.4mm





p(pbar) on Al,Be,Si(5cm) - 10K pguns

Aluminium:

PGUN	P (GeV/c)	Nint/Ngen	Err	Ratio pbar/p
p	1.	0.1679	0.0037	2.89±0.07
pbar	1.	0.4851	0.0050	
p	5.	0.1778	0.0038	1.43±0.04
pbar	5.	0.2548	0.0044	
p	10.	0.1746	0.0038	1.16±0.03
pbar	10.	0.2029	0.0040	
p	100.	0.1711	0.0038	0.91±0.03
pbar	100.	0.1565	0.0036	

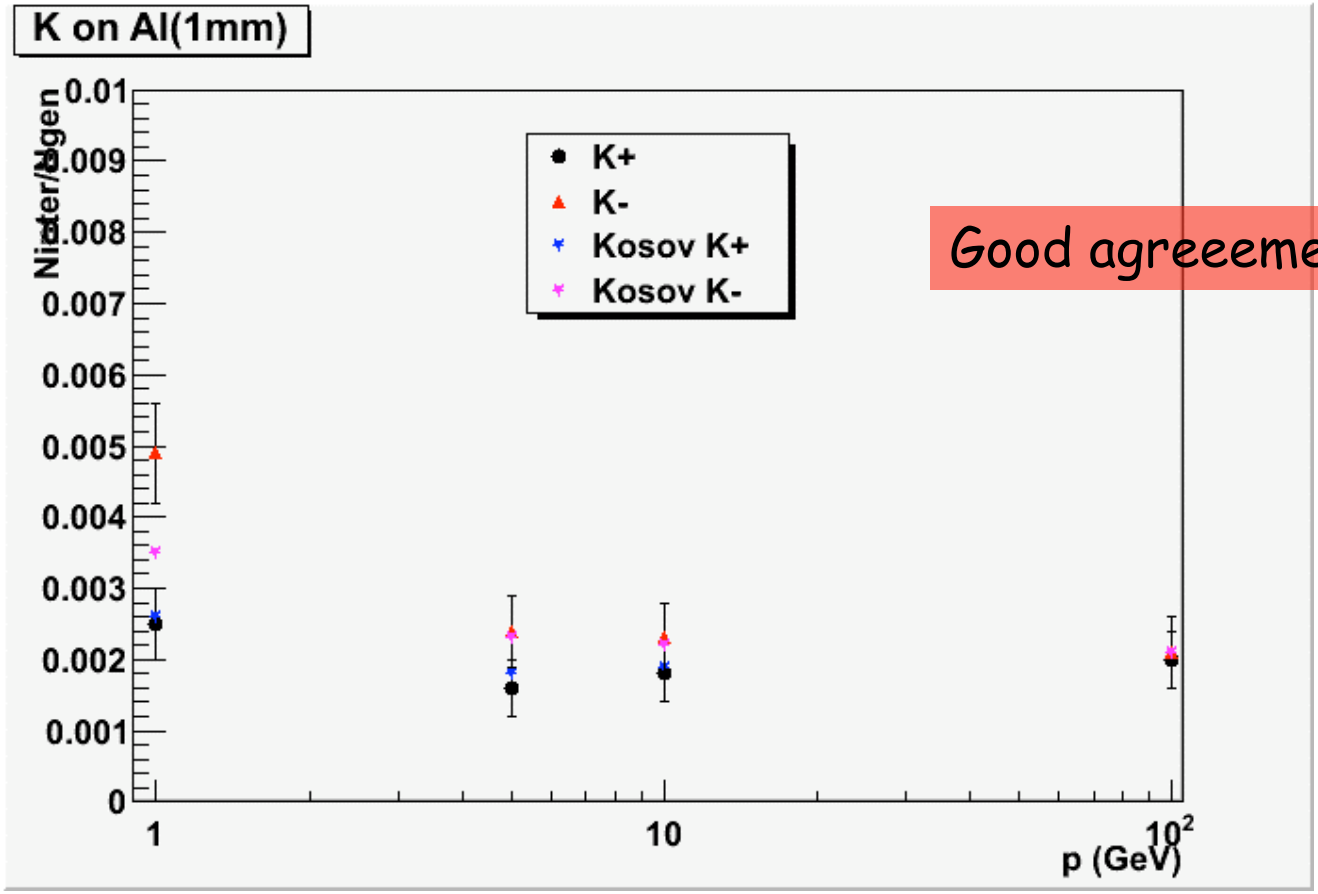
Beryllium:

PGUN	P (GeV/c)	Nint/Ngen	Err	Ratio pbar/p
p	1.	0.1372	0.0034	3.11±0.08
pbar	1.	0.4274	0.0049	
p	5.	0.1521	0.0036	1.51±0.04
pbar	5.	0.2300	0.0042	
p	10.	0.1511	0.0036	1.23±0.04
pbar	10.	0.1863	0.0039	
p	100.	0.1474	0.0035	0.99±0.03
pbar	100.	0.1454	0.0035	

Silicon:

PGUN	P (GeV/c)	Nint/Ngen	Err	Ratio pbar/p
p	1.	0.1443	0.0035	3.00±0.08
pbar	1.	0.4328	0.0049	
p	5.	0.1560	0.0036	1.42±0.04
pbar	5.	0.2219	0.0041	
p	10.	0.1542	0.0036	1.14±0.04
pbar	10.	0.1764	0.0038	
p	100.	0.1489	0.0036	0.92±0.03
pbar	100.	0.1368	0.0034	

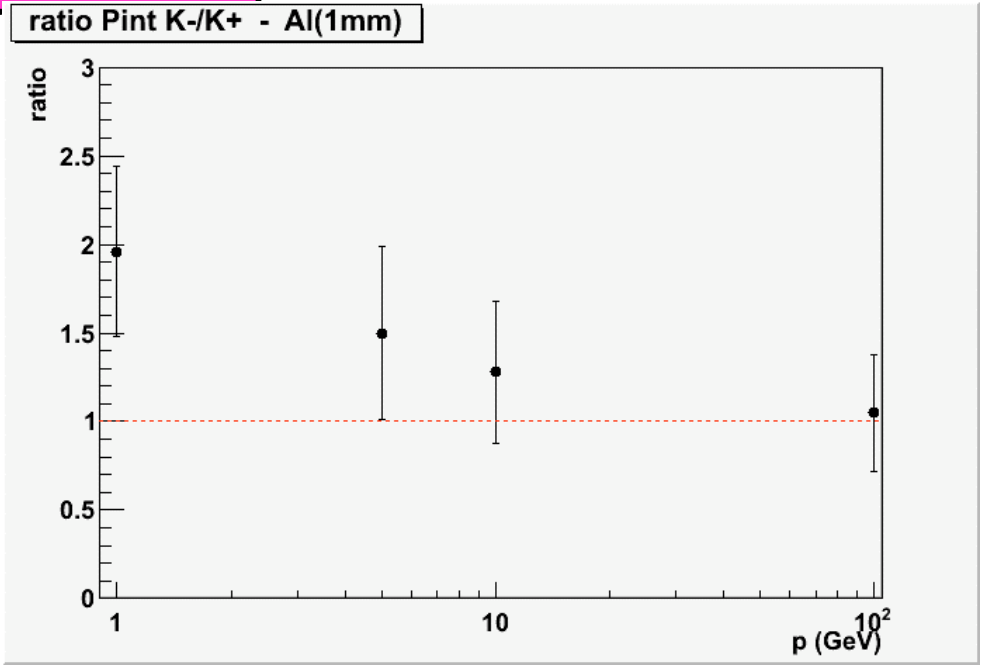
K+(K-) on Al (1mm)



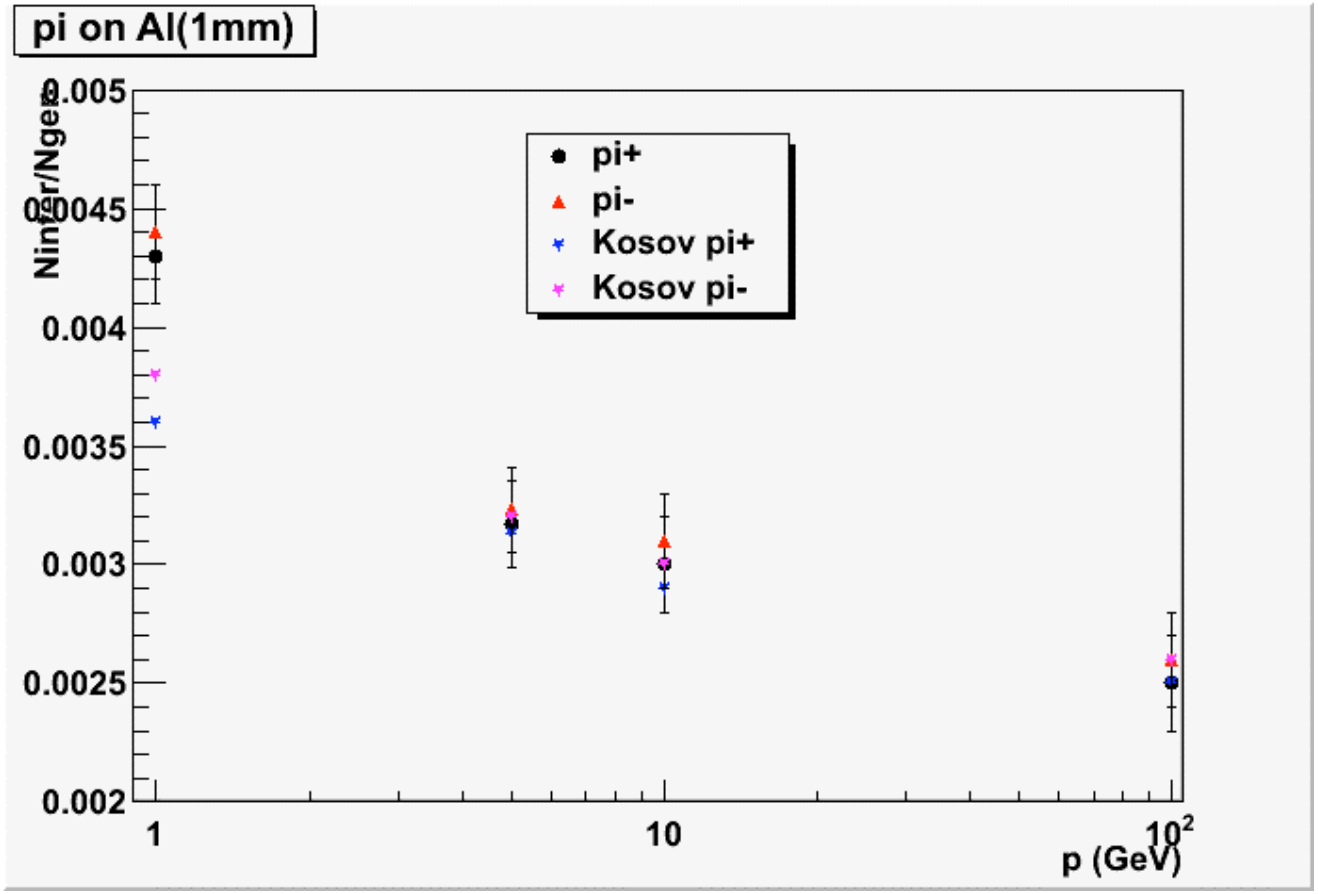
Good agreeement found

K+(K-) on Al (1mm) - 10k

PGUN	P (GeV/c)	Nint/Ngen	Err	Ratio k-/k+
K+	1.	0.0025	0.0005	1.96±0.48
K-	1.	0.0049	0.0007	
K+	5.	0.0016	0.0004	1.50±0.49
K-	5.	0.0024	0.0005	
K+	10.	0.0018	0.0004	1.28±0.40
K-	10.	0.0023	0.0005	
K+	100.	0.0020	0.0004	1.05±0.33
K-	100.	0.0021	0.0005	

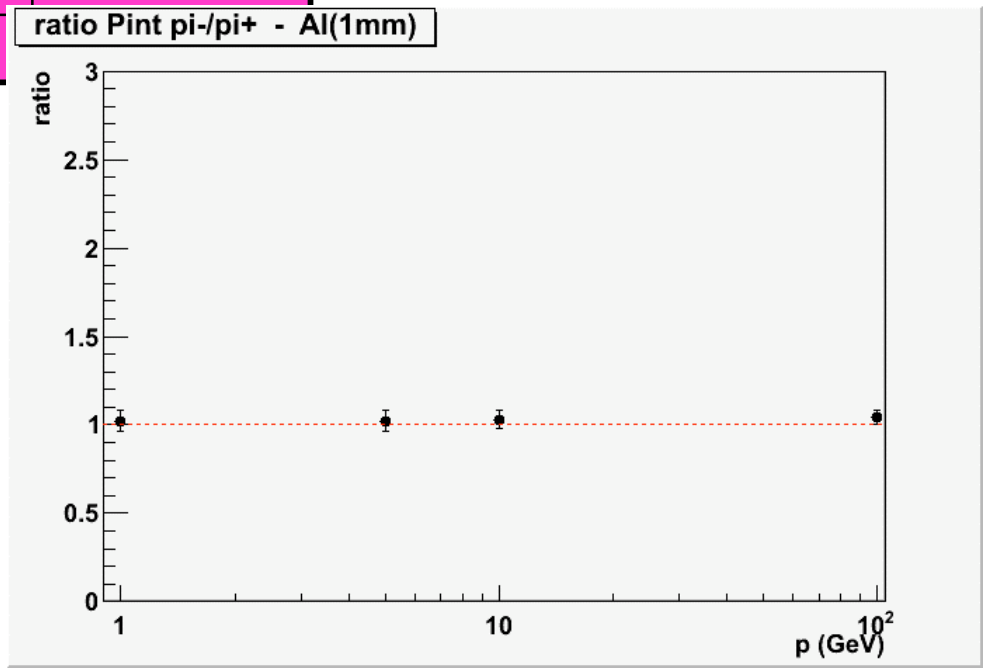


pi+(pi-) on Al (1mm) - 100K pguns



pi+(pi-) on Al (1mm) - 100K pguns

PGUN	P (GeV/c)	Nint/Ngen	Err	Ratio pi-/pi+
Pi+	1.	0.0043	0.0002	1.02±0.07
Pi-	1.	0.0044	0.0002	
Pi+	5.	0.00317	0.00018	1.02±0.08
Pi-	5.	0.00323	0.00018	
Pi+	10.	0.0030	0.0002	1.03±0.10
Pi-	10.	0.0031	0.0002	
Pi+	100.	0.0025	0.0002	1.04±0.11
Pi-	100.	0.0026	0.0002	

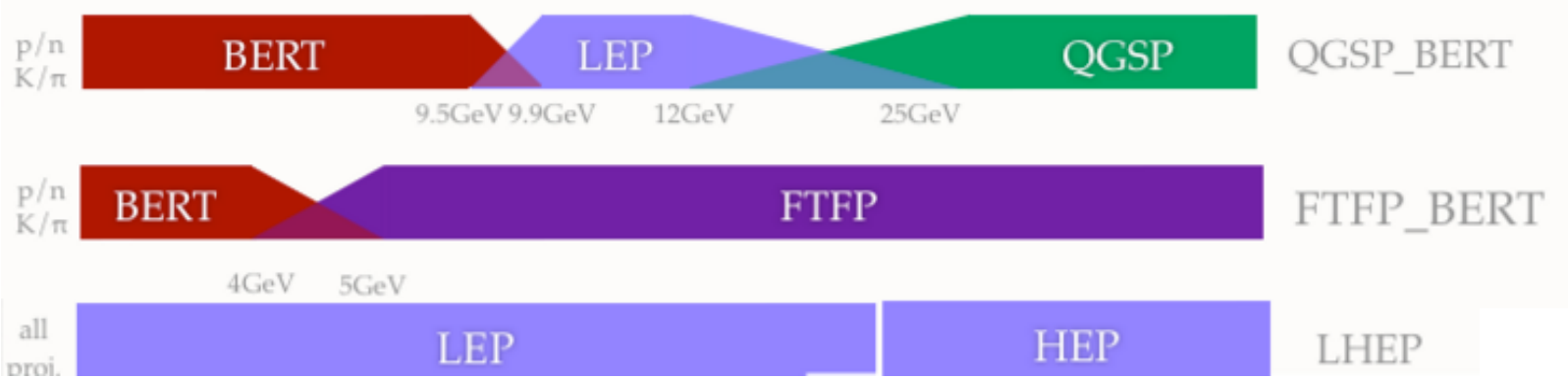


07/07/2010

Cross sections and multiplicities with different PLs

- Important to test the variation of:
  - cross sections
  - multiplicity in inelastic hadronic interactions

  using different PLs: LHEP, QGSP_BERT, FTFP_BERT
- Same geometric setup as in the P_{int} exercise
- PGUNs of ppbar, K+- and pi+- (same random seed used)



p (pbar) on Al (1mm)

- Ngenerated = 100K (1 p per event)

PGUN	P (GeV/c)	Nint (LHEP)	Nint (QGSPBERT)	Nint (FTFPBERT)	<Mult> (LHEP)	RMS (LHEP)	<Mult> (QGSPBERT)	RMS (QGSPBERT)	<Mult> (FTFPBERT)	RMS (FTFPBERT)
p	1.	375	401	401	10.7	4.30	8.41	2.93	8.41	2.93
pbar	1.	1336	1336	1336	11.2	4.64	11.2	4.64	11.2	4.64
p	5.	401	407	407	14.07	5.09	13.31	6.53	13.55	6.38
pbar	5.	602	602	602	14.3	5.54	14.3	5.54	14.3	5.54
p	10.	392	399	399	9.19	3.74	16.72	8.35	12.2	4.36
pbar	10.	470	470	470	10.22	3.81	10.22	3.81	10.22	3.81
p	13.	391	398	398	10.2	3.89	10.43	4.02	12.53	4.67
pbar	13.	446	446	446	11.25	4.18	11.25	4.18	11.25	4.18
p	100.	377	384	384	16.26	8.03	21.0	10.09	19.12	8.80
pbar	100.	332	332	332	17.04	7.93	17.04	7.93	17.04	7.93

- pbar cross sections and multiplicities are the same for all the PLs considered
- p cross sections using LHEP lower than QGSP_BERT(=FTFP_BERT)
  - 6.5% at p=1GeV, ~1.7% at p>5GeV
- p multiplicities different for all PLs (except QGSPBERT and FTFPBERT at p=1GeV) -> same model used at low energies (E<4GeV)

p (pbar) on Al (5cm)

- Ngenerated = 10K (1 p per event)

PGUN	P (GeV/c)	Nint(LHEP)	Nint(QGSPBERT)	Nint(FTFPBERT)	<Mult> (LHEP)	<Mult> (QGSPBERT)	<Mult> (FTFPBERT)
p	1.	1679	1814	1814	10.66	8.27	8.27
pbar	1.	4851	4851	4851	11.19	11.19	11.19
p	5.	1778	1810	1810	14.2	13.97	13.38
pbar	5.	2548	2548	2548	14.74	14.74	14.74
p	10.	1746	1780	1780	9.51	17.08	12.54
pbar	10.	2029	2029	2029	10.21	10.21	10.21
p	100.	1711	1745	1745	16.69	20.19	19.67
pbar	100.	1565	1565	1565	16.67	16.67	16.67

- same conclusions as in the 1mm case...

p Al (1mm)

• Ngenerated = 10K (1 p per event)

Which kind of particles generates from a ProtonInelastic process? (24 inelastic interactions for pAl (p at 10GeV)

FTFP_BERT

2212 proton
2112 neutron
111 pi0
211(-211) pi+-

3122 lambda

22 gamma

1000010020 deuteron
1000020040 alpha

1000130260 Al26[0.0]
1000090200 F20[0.0]

1000100200 Ne20[0.0]

1000110220 Na22[0.0]
1000110230 Na23[0.0]

1000120240 Mg24[0.0]
1000120260 Mg26[0.0]

QGSP_BERT

2212 proton
2112 neutron
111 pi0
211(-211) pi+-

22 gamma

1000010020 deuteron
1000020040 alpha
1000010030 triton
1000020030 He3

1000040080 Be8[0.0]
1000040090 Be9[0.0]

1000100200 Ne20[0.0]
1000100210 Ne21[0.0]

1000110230 Na23[0.0]
1000110220 Na22[0.0]

1000120240 Mg24[0.0]
1000120260 Mg26[0.0]

1000030070 Li7[0.0]

1000060100 C10[0.0]

LHEP

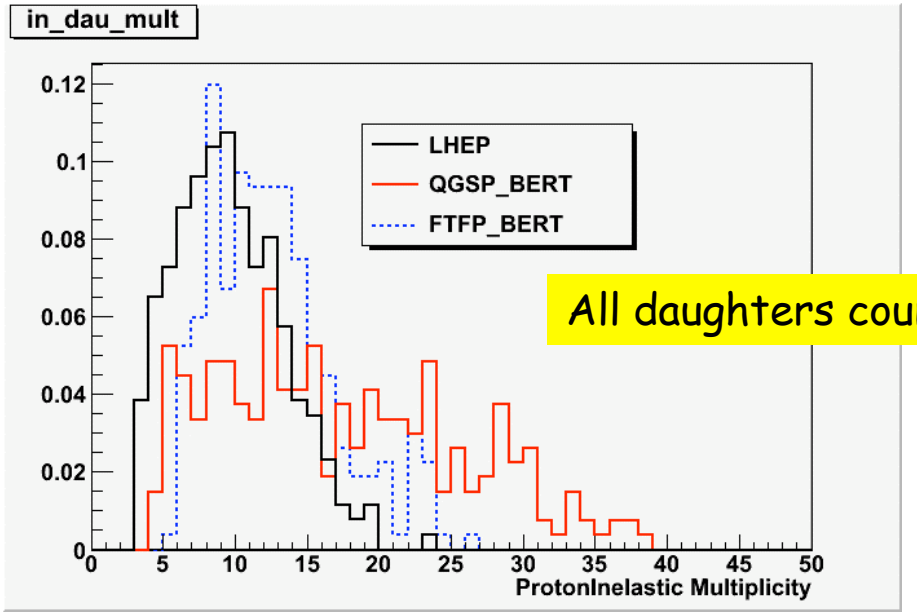
2212 proton
2112 neutron
111 pi0
211(-211) pi+-

3122 lambda

ppbarAl (1mm)

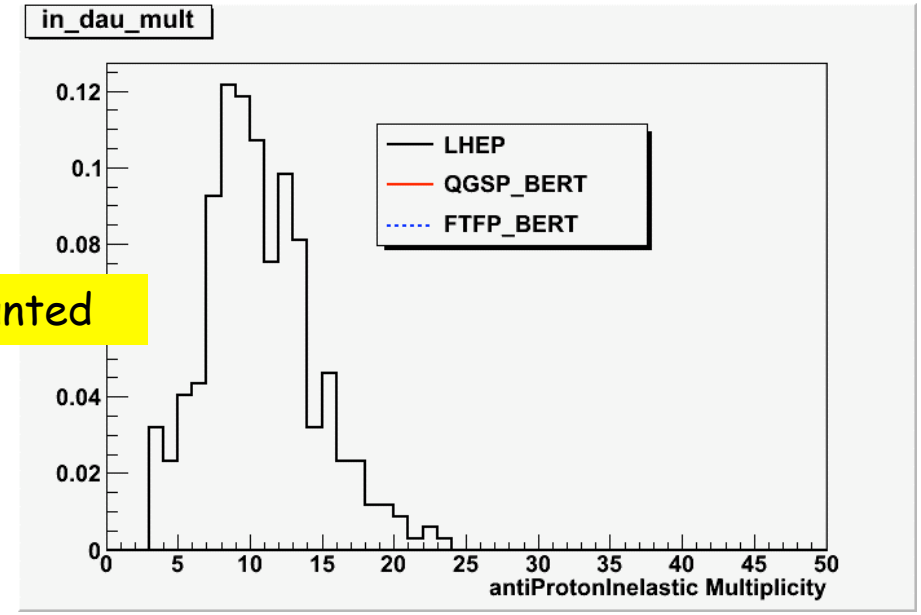
• Ngenerated = 100K (1 p per event)

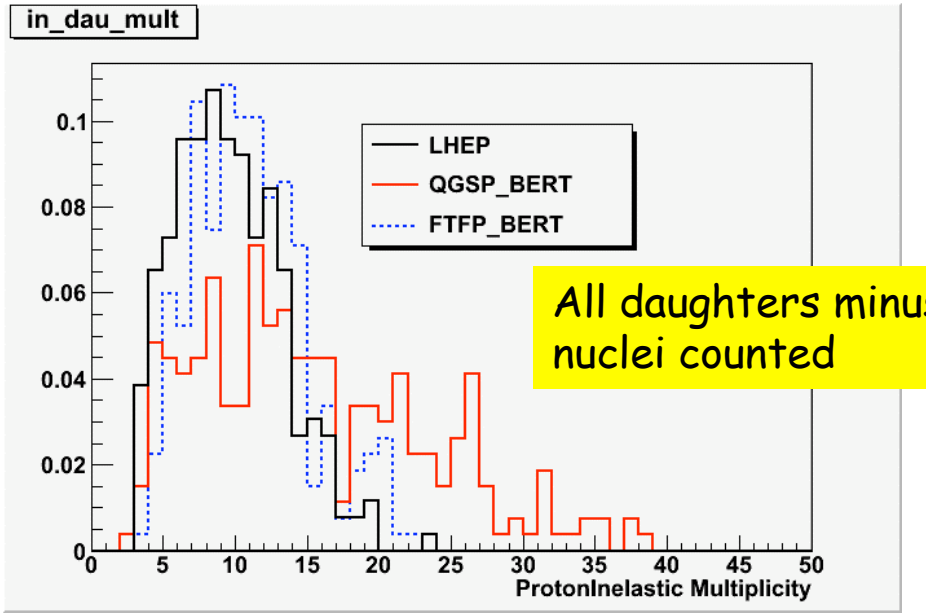
pAl (p at 10GeV)



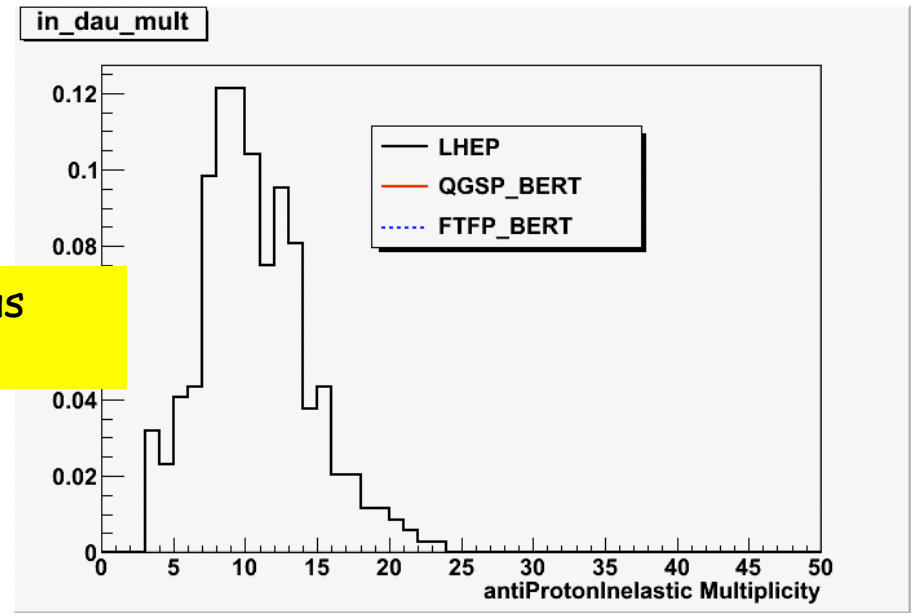
All daughters counted

pbarAl (p at 10GeV)





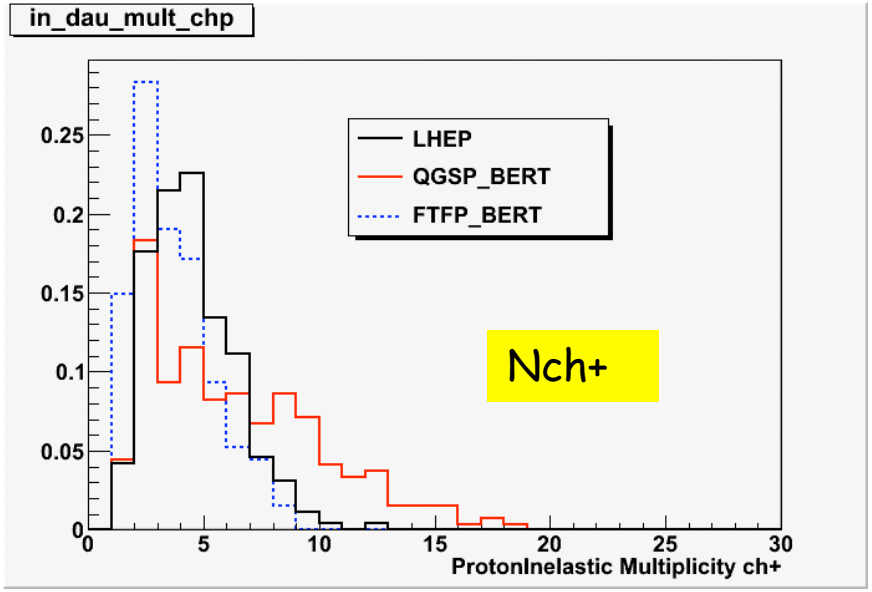
All daughters minus nuclei counted

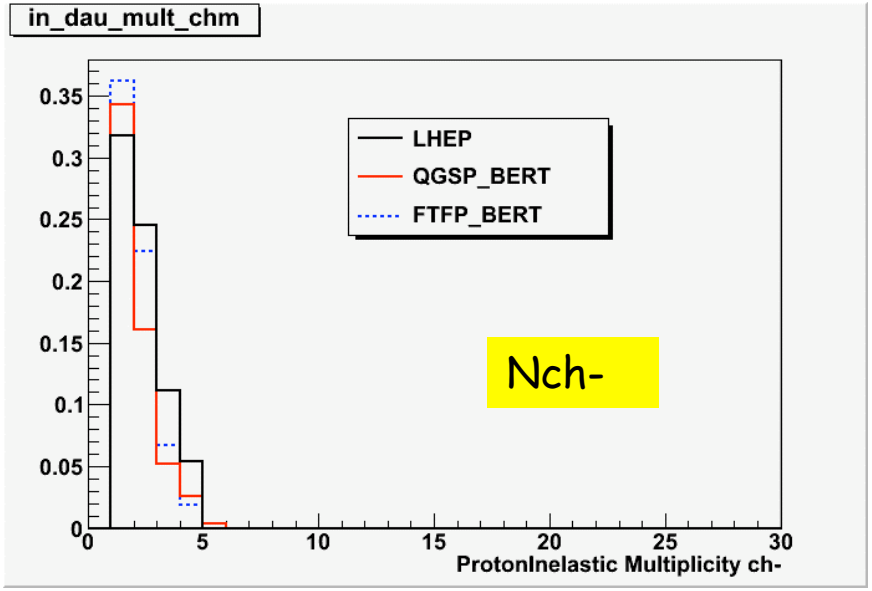


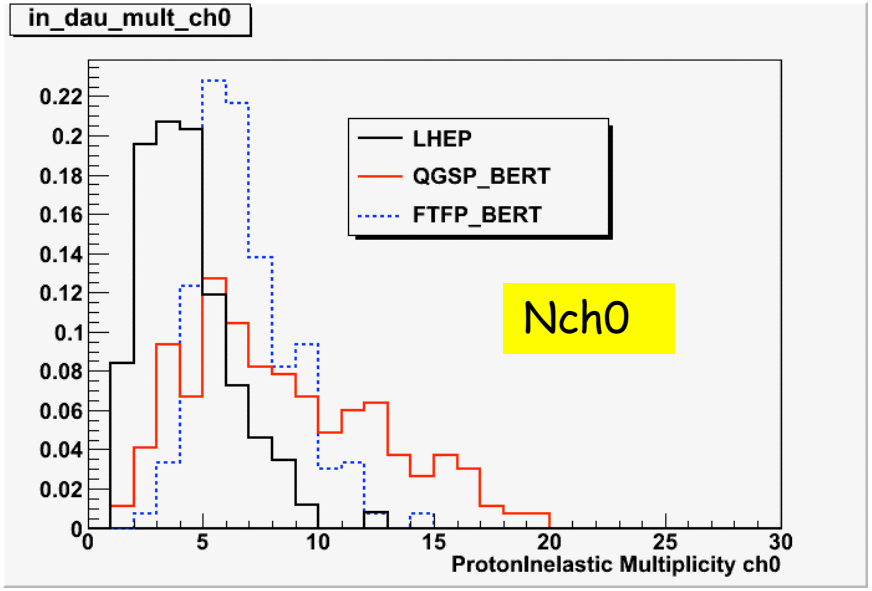
pAl (1mm)

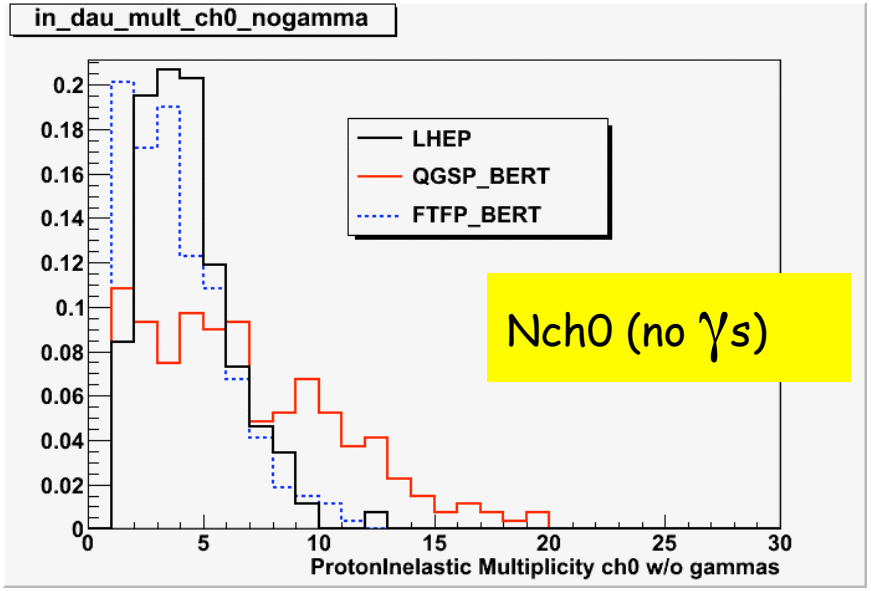
• Ngenerated = 100K (1 p per event)

Multiplicity in ProtonInelastic w/o considering the nuclei in daughters count





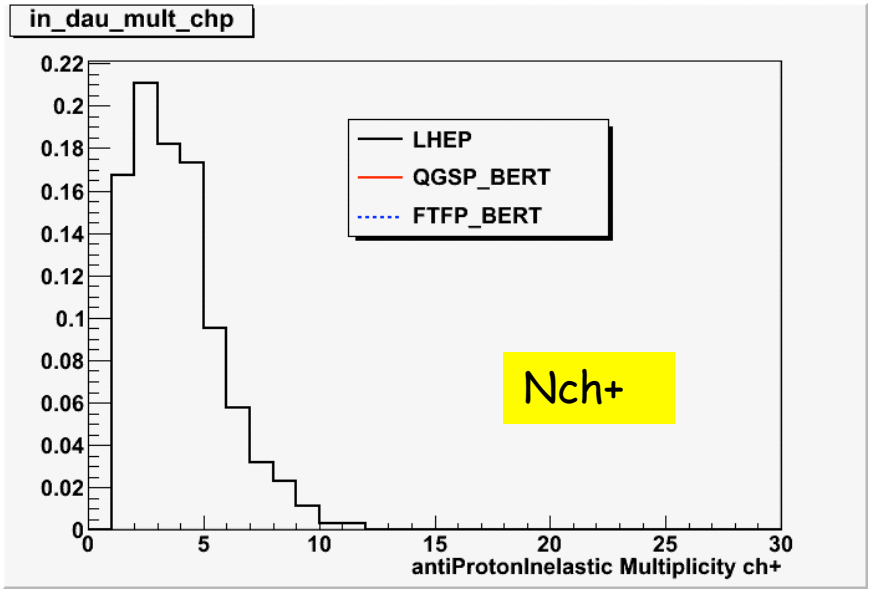


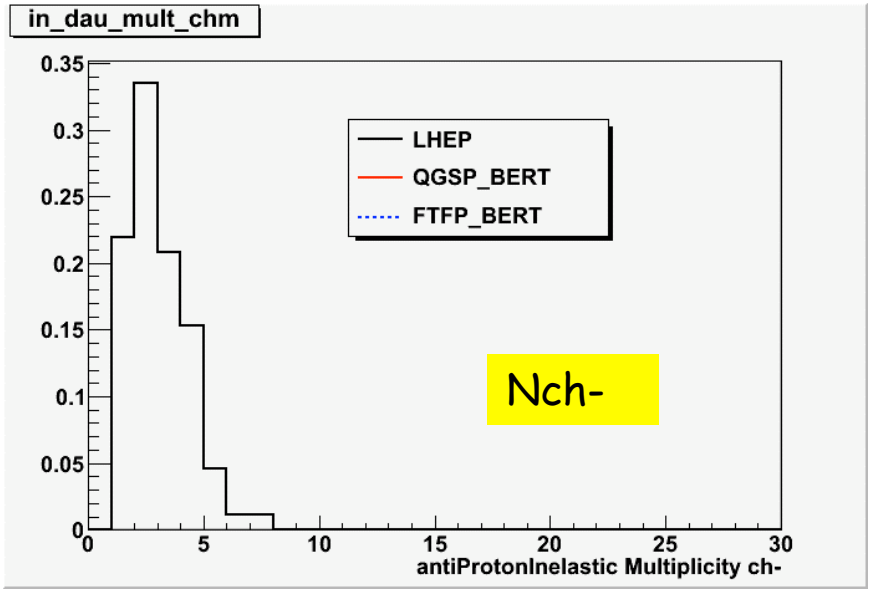


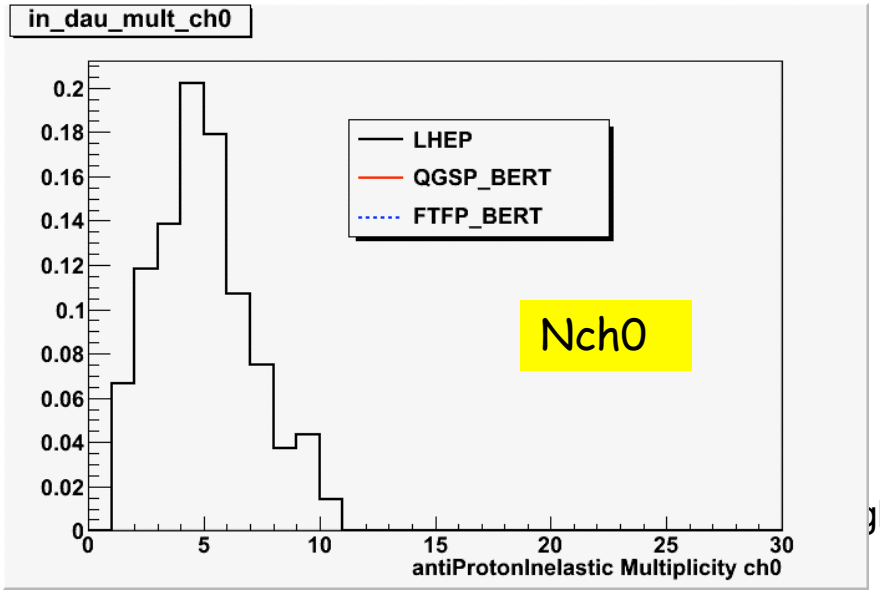
pbar Al (1mm)

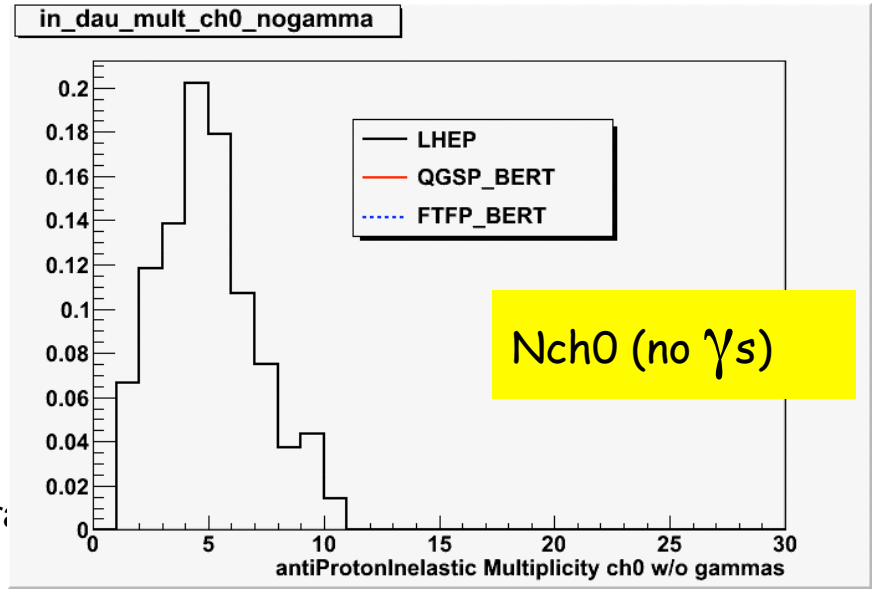
• Ngenerated = 100K (1 p per event)

Multiplicity in antiProtonInelastic w/o considering the nuclei in daughters count



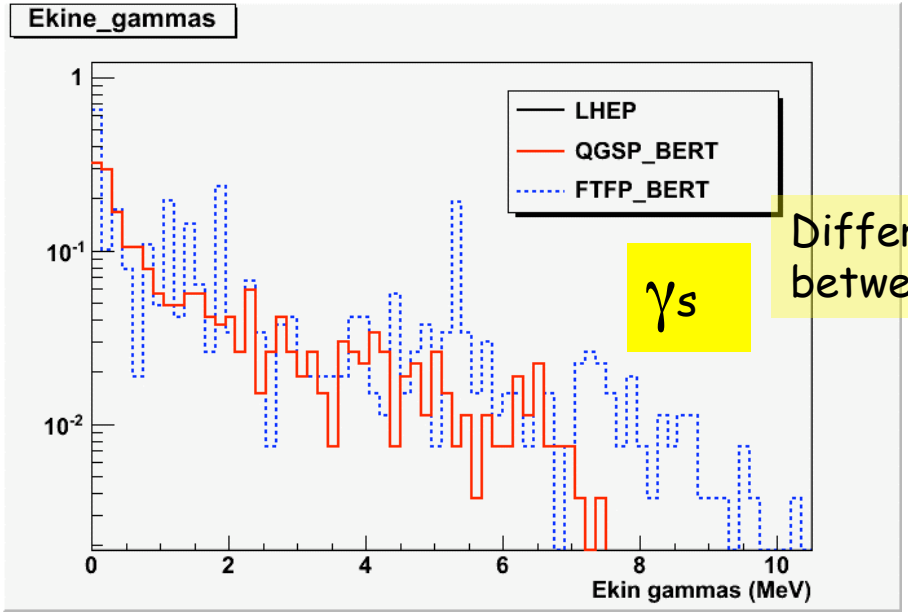






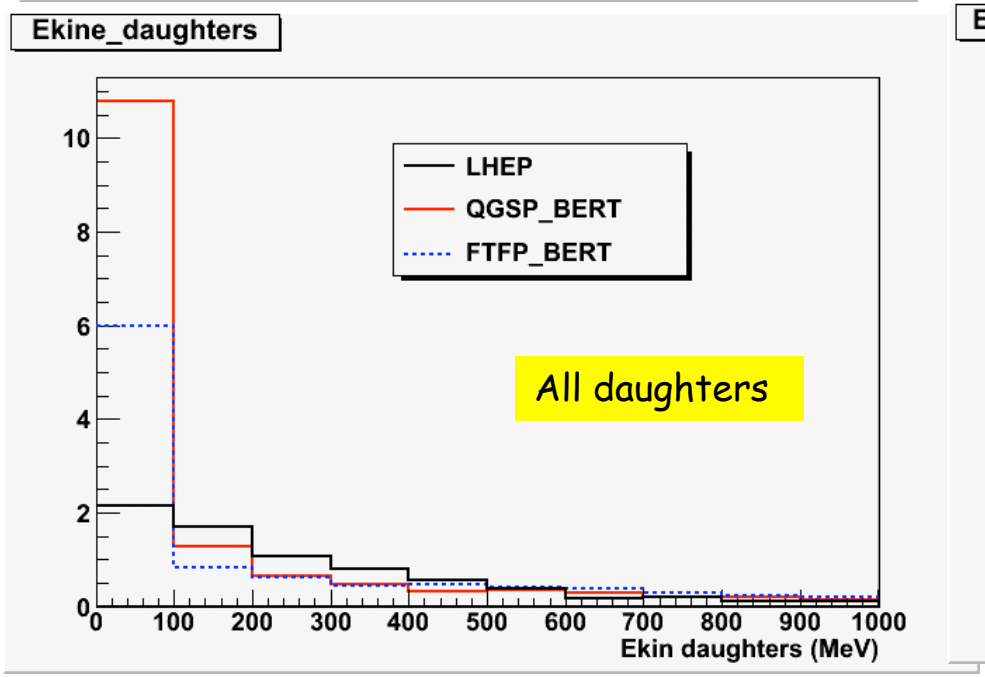
p Al (1mm)

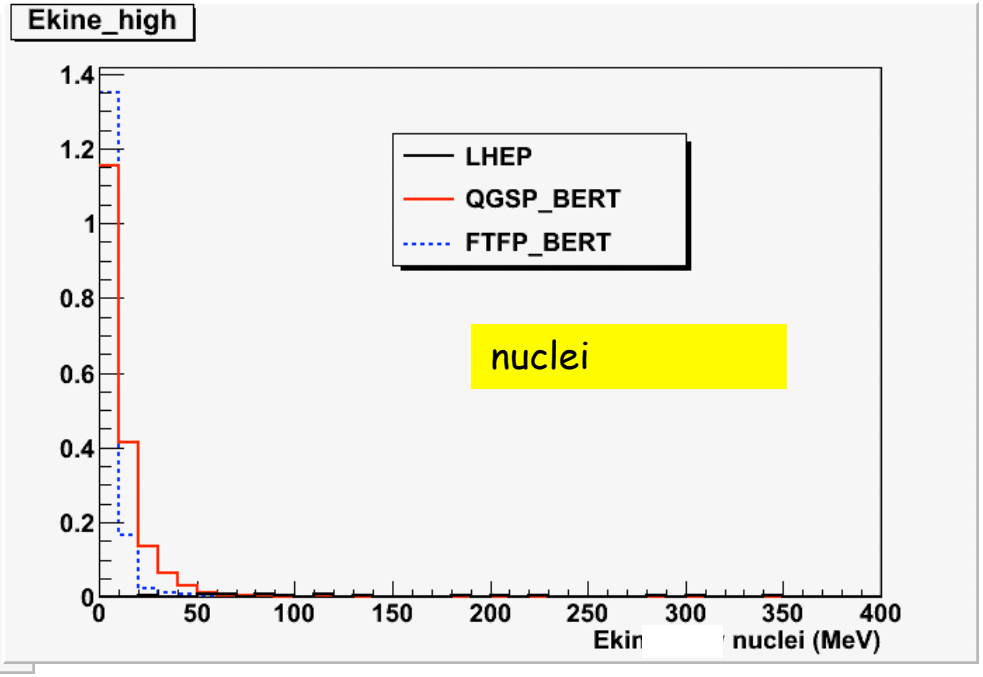
Kinetic Energy



Different Ekin spectrum for gammas between QGSP_BERT and FTFP_BERT

Many gammas are being produced with a Kinetic energy below the gammas Ekine threshold set in LHCb (1 MeV).





K+(K-) on Al (1mm)

- Ngenerated = 100K (1 k per event)

PGUN	P (GeV/c)	Nint (LHEP)	Nint (QGSPBERT)	Nint (FTFPBERT)	<Mult> (LHEP)	RMS (LHEP)	<Mult> (QGSPBERT)	RMS (QGSPBERT)	<Mult> (FTFPBERT)	RMS (FTFPBERT)
K+	1.	256	256	256	9.6	3.66	8.905	3.36	8.905	3.36
K-	1.	499	499	499	11.77	6.45	12.46	5.85	12.46	5.85
K+	5.	176	176	176	14.59	6.12	15.12	6.72	12.53	5.63
K-	5.	238	238	238	13.81	5.47	16.87	7.17	13.91	6.16
K+	10.	186	186	186	9.76	3.76	17.6	8.67	11.37	3.27
K-	10.	232	232	232	9.91	3.97	18.73	8.21	12.15	3.53
K+	13.	190	190	190	10.51	4.21	10.59	4.35	11.94	3.40
K-	13.	229	229	229	11.15	4.55	11.02	4.93	12.47	3.59
K+	100.	205	205	205	16.78	8.07	17.29	8.40	18.07	7.17
K-	100.	214	214	214	16.39	7.34	17.36	8.29	18.55	6.98

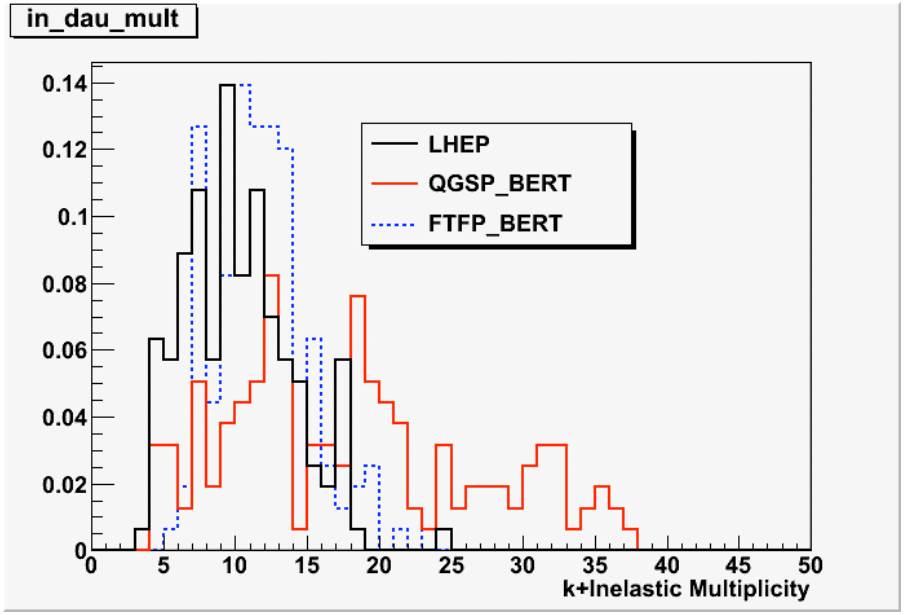
- K+ and K- cross sections are the same for all the PLs considered
- K+- multiplicities different for all PLs (except QGSPBERT and FTFPBERT at p=1GeV) -> same model used at low energies (E<4GeV)

K+Al (1mm)

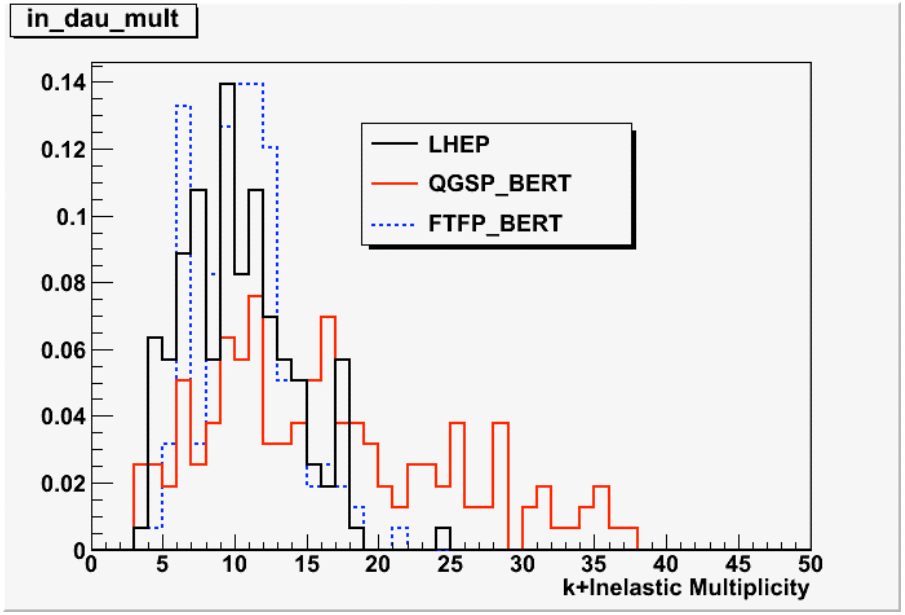
• Ngenerated = 100K (1 K+ per event)

K+Al (K+ at 10GeV)

All daughters counted



All daughters minus nuclei counted



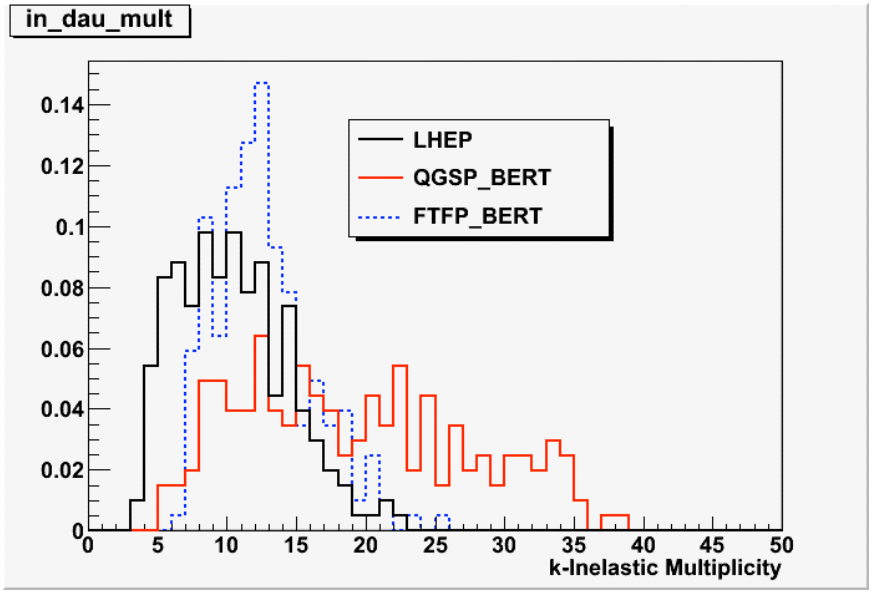
07/07/2010

K-Al (1mm)

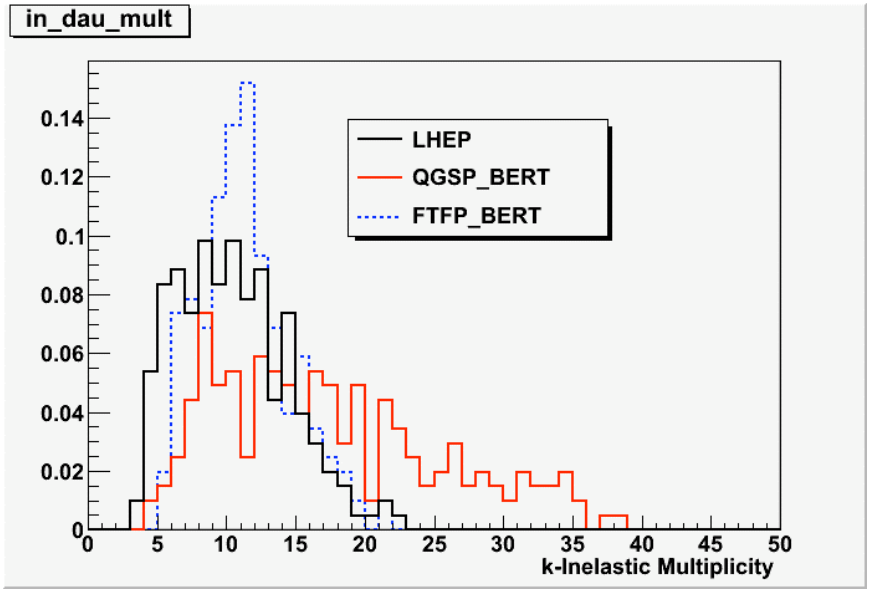
• Ngenerated = 100K (1 k- per event)

K-Al (k- at 10GeV)

All daughters counted



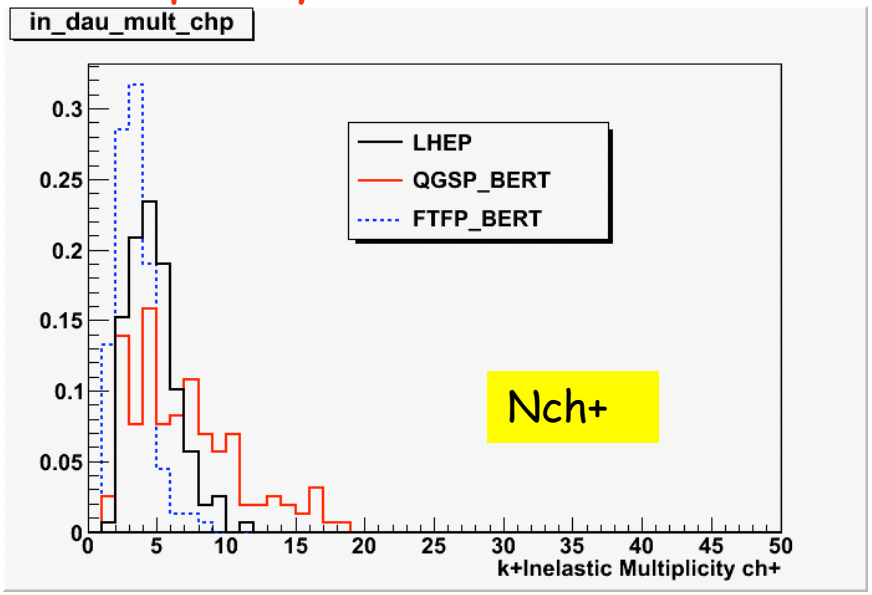
All daughters minus nuclei counted

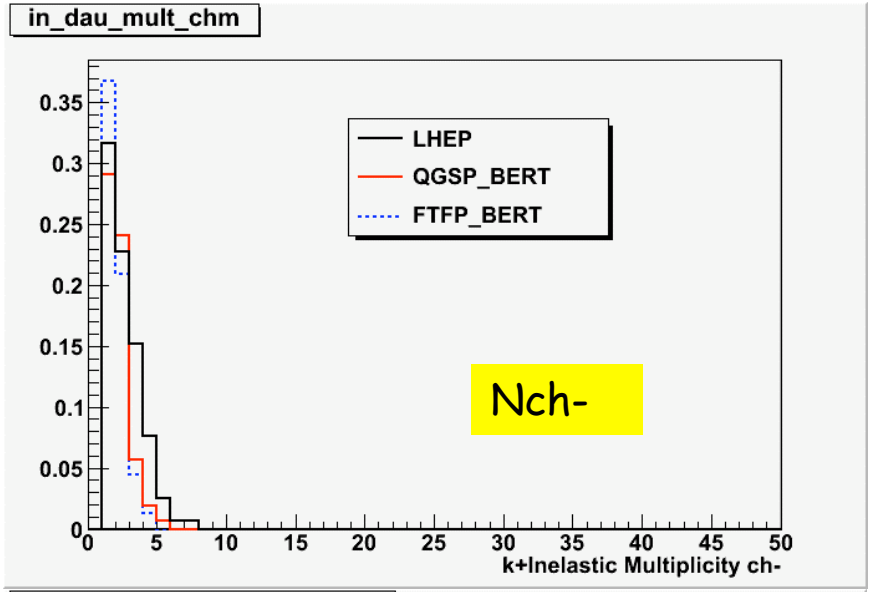


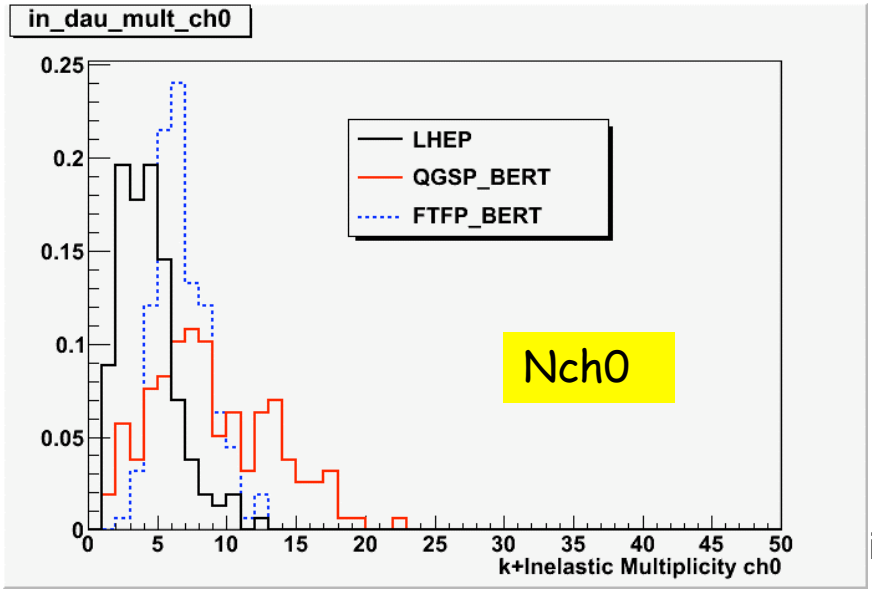
k+Al (1mm)

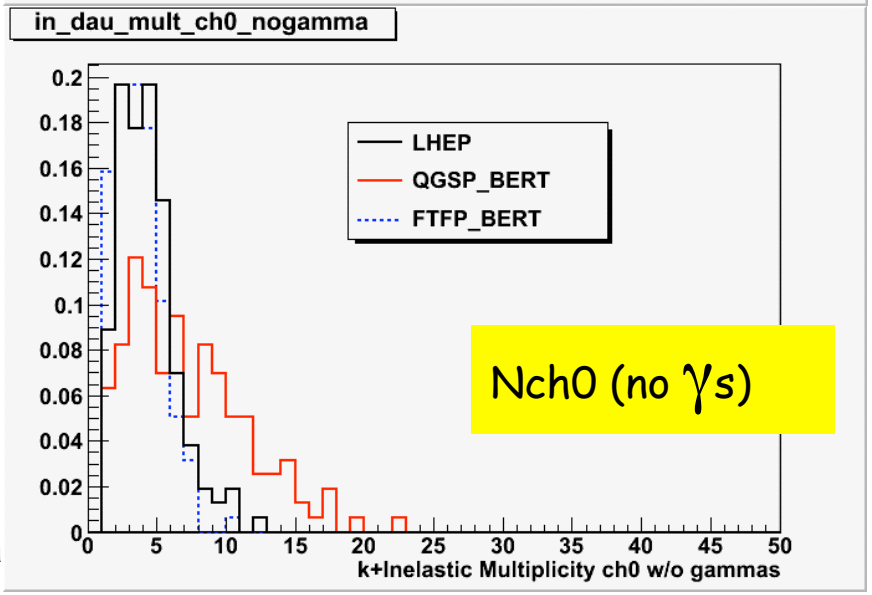
• Ngenerated = 100K (1 k+ per event)

Multiplicity in K+Inelastic w/o considering the nuclei in daughters count







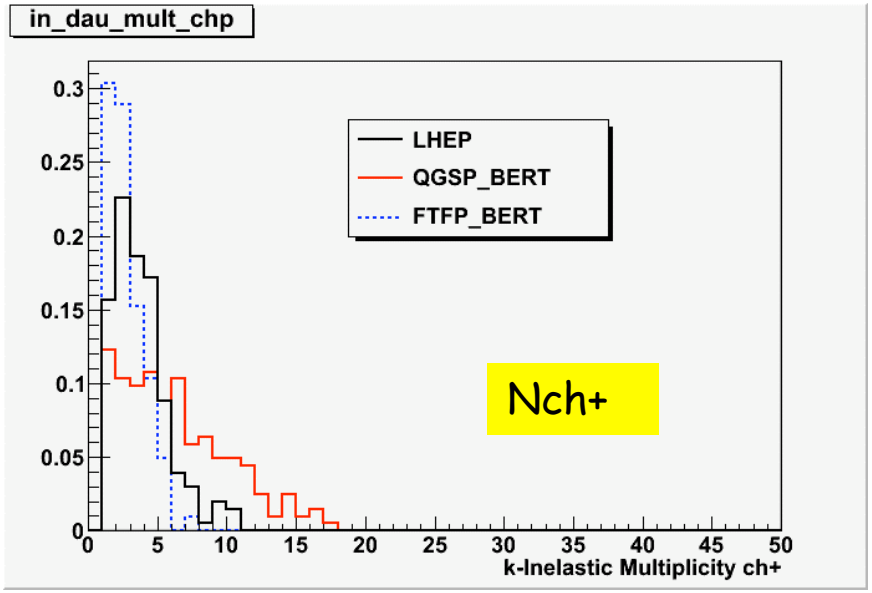


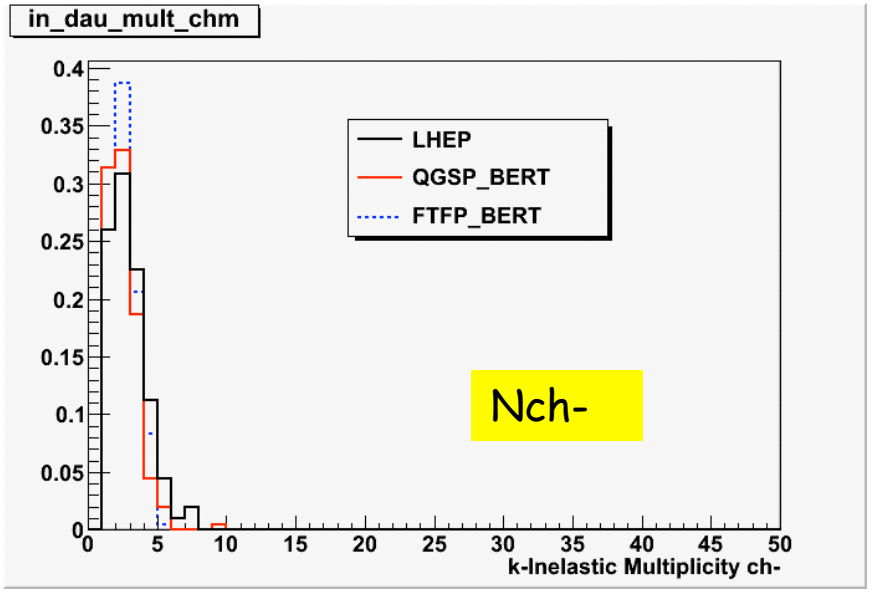
iora

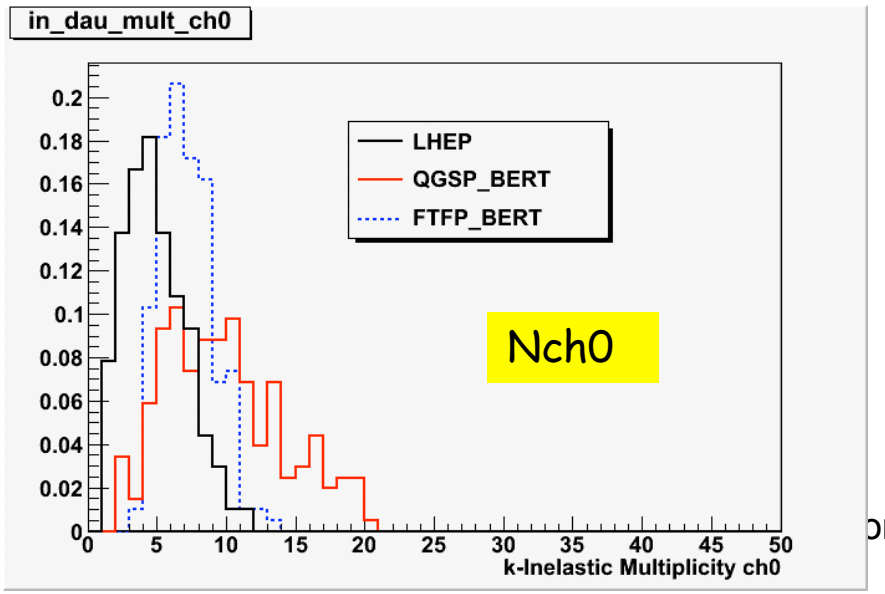
K-Al (1mm)

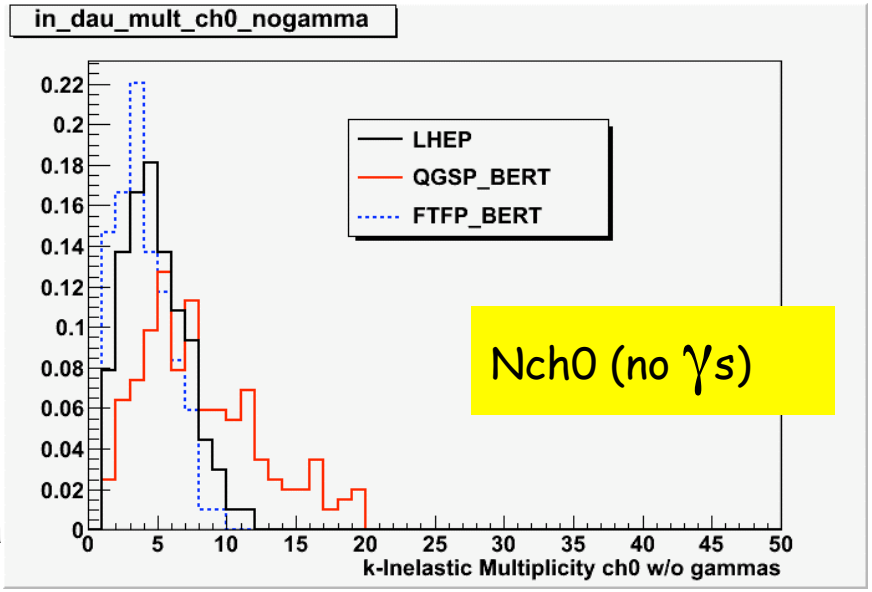
• Ngenerated = 100K (1 k- per event)

Multiplicity in K-Inelastic w/o considering the nuclei in daughters count









pi+(pi-) on Al (1mm)

- Ngenerated = 100K (1 pi per event)

PGUN	P (GeV/c)	Nint (LHEP)	Nint (QGSPBERT)	Nint (FTFPBERT)	<Mult> (LHEP)	RMS (LHEP)	<Mult> (QGSPBERT)	RMS (QGSPBERT)	<Mult> (FTFPBERT)	RMS (FTFPBERT)
pi+	1.	428	435	435	9.84	4.06	10.13	4.44	10.13	4.44
pi-	1.	438	435	435	9.40	3.82	10.5	4.39	10.5	4.39
pi+	5.	317	331	331	14.94	5.72	16.62	7.30	11.88	4.16
pi-	5.	323	331	331	13.92	5.56	16.43	7.41	12.03	4.4
pi+	10.	301	307	307	10.02	3.88	11.00	5.59	12.22	3.7
pi-	10.	307	307	307	10.16	4.01	10.96	5.74	12.25	3.72
pi+	13.	291	297	297	11.47	4.90	11.64	5.06	12.79	4.15
pi-	13.	297	297	297	11.47	4.47	10.94	4.55	12.73	4.29
pi+	100.	255	250	250	17.24	8.75	18.94	8.42	17.75	7.58
pi-	100.	261	250	250	16.98	7.58	18.63	8.46	17.83	7.44

- pi+ and pi- cross sections are the same for QGSP_BERT and FTFP_BERT. LHEP cross sections are slightly different (few %)
- σ(pi+) = σ(pi-) for QGSP_BERT and FTFP_BERT
- pi +- multiplicities different for all PLs (except QGSPBERT and FTFPBERT at p=1GeV) -> same model used at low energies (E<4GeV)

Multiplicities in MinBias events

- 1K MinBias samples considered
- LHCb full geometry simulated
- Geant 9.2p3 (delta rays simulated)
- Events were processed through the chain:

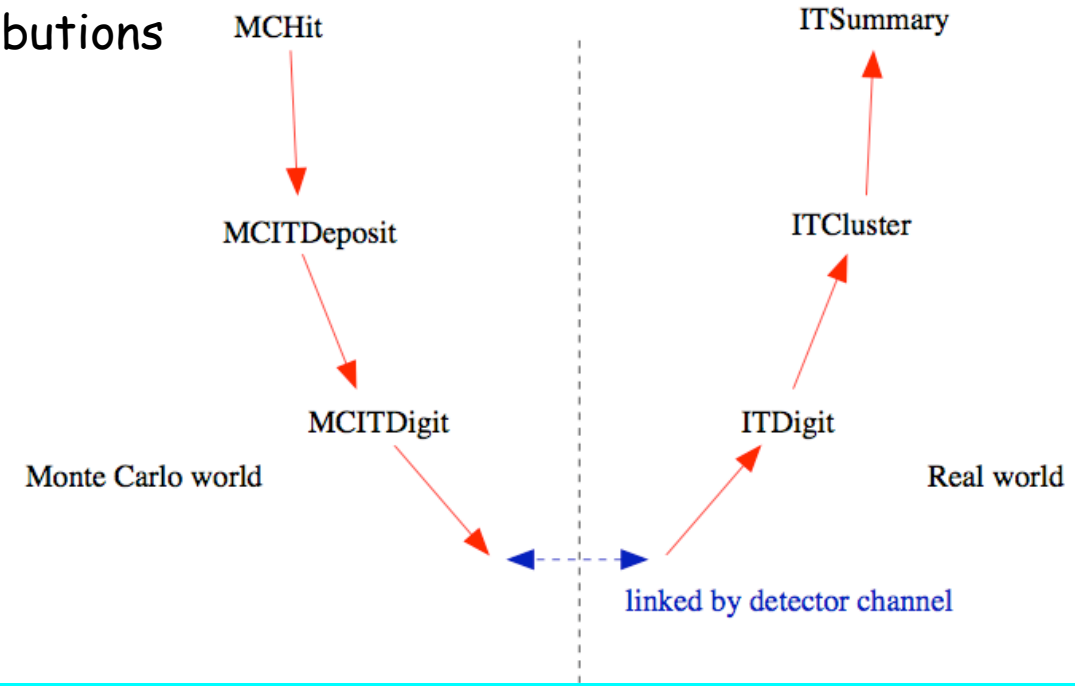
  Simulation -> Digitization -> Reconstruction

  to monitor how the MCHits evolve during the digitization and clustering steps
- focus on the trackers distributions

Comparison between:

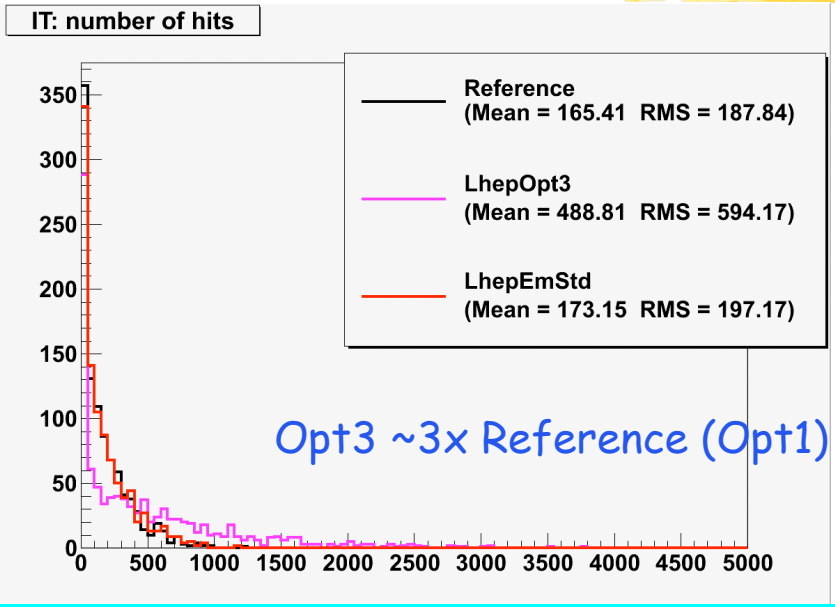
- EmOpt1 (Reference)
- EmStd
- EmOpt3

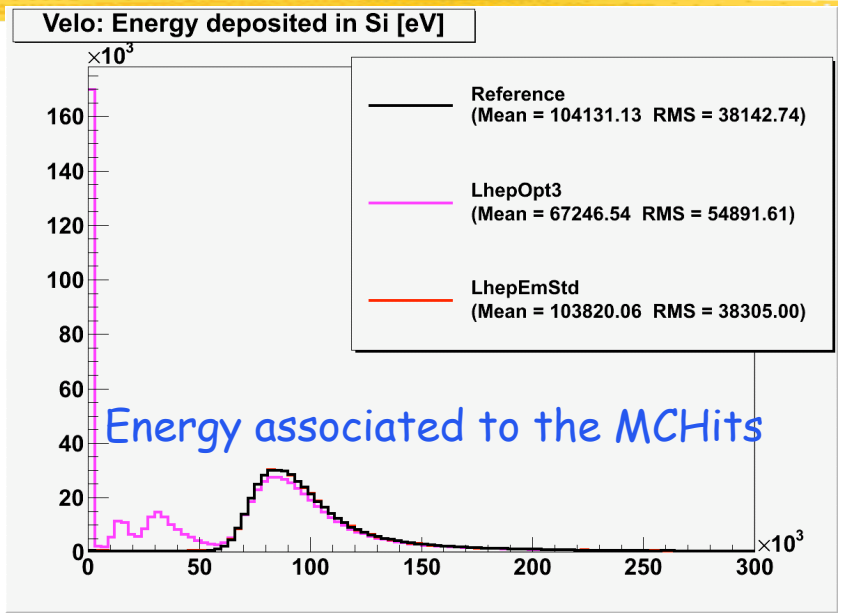
- LHEP (Reference)
- QGSPBERT
- FTFP_BERT



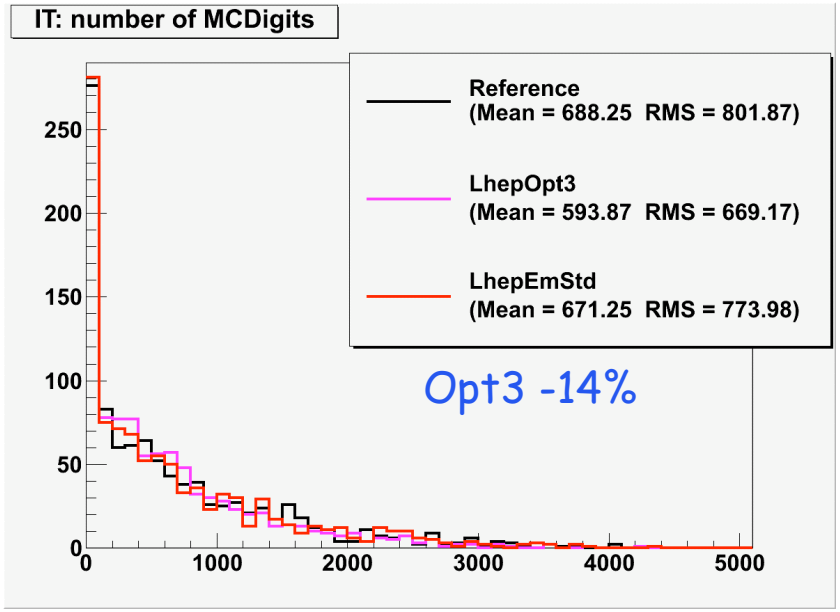
No significant differences found changing the hadronic PLs -> only Em tests shown here

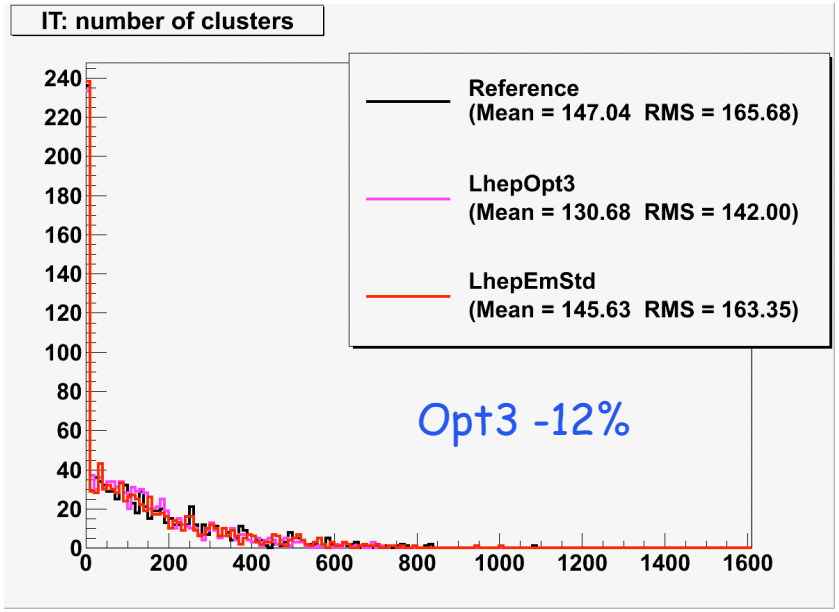
Comparison MCHits using different Em packages (Opt1,Opt3 and Std)





Number of MCHits in the trackers using EmOpt3 increases from +40% to a factor 3





... few words on CPU time

1K MinBias samples produced on a dedicated slc5 machine. K. Kruzelecki

Default setting: EmOpt1 and LHEP: 201 min

Em Physics Lists:

- EMOpt3: 395 min (+97%)
- EmStd: 231 min (+15%)

Hadronic Physics Lists:

. QGSP_BERT: 219 min (+9%)
- FTFP_BERT: 219 min (+9%)

conclusions

•Attempt to estimate the systematic errors in particle/anti-particle reconstruction caused by uncertainties of Geant4 MC cross-sections was done

• Interaction probability have been measured with the simplified geometry for protons, kaons and pions for different targets

• The comparison of the simplified geometry results with LHEP fits showed good agreement (cross-check successful)

• To be noticed: K+/K- do have different cross sections

• Particle multiplicity using different PLs was studied, both with PGUN ans MinBias events (using LHCb full geometry).

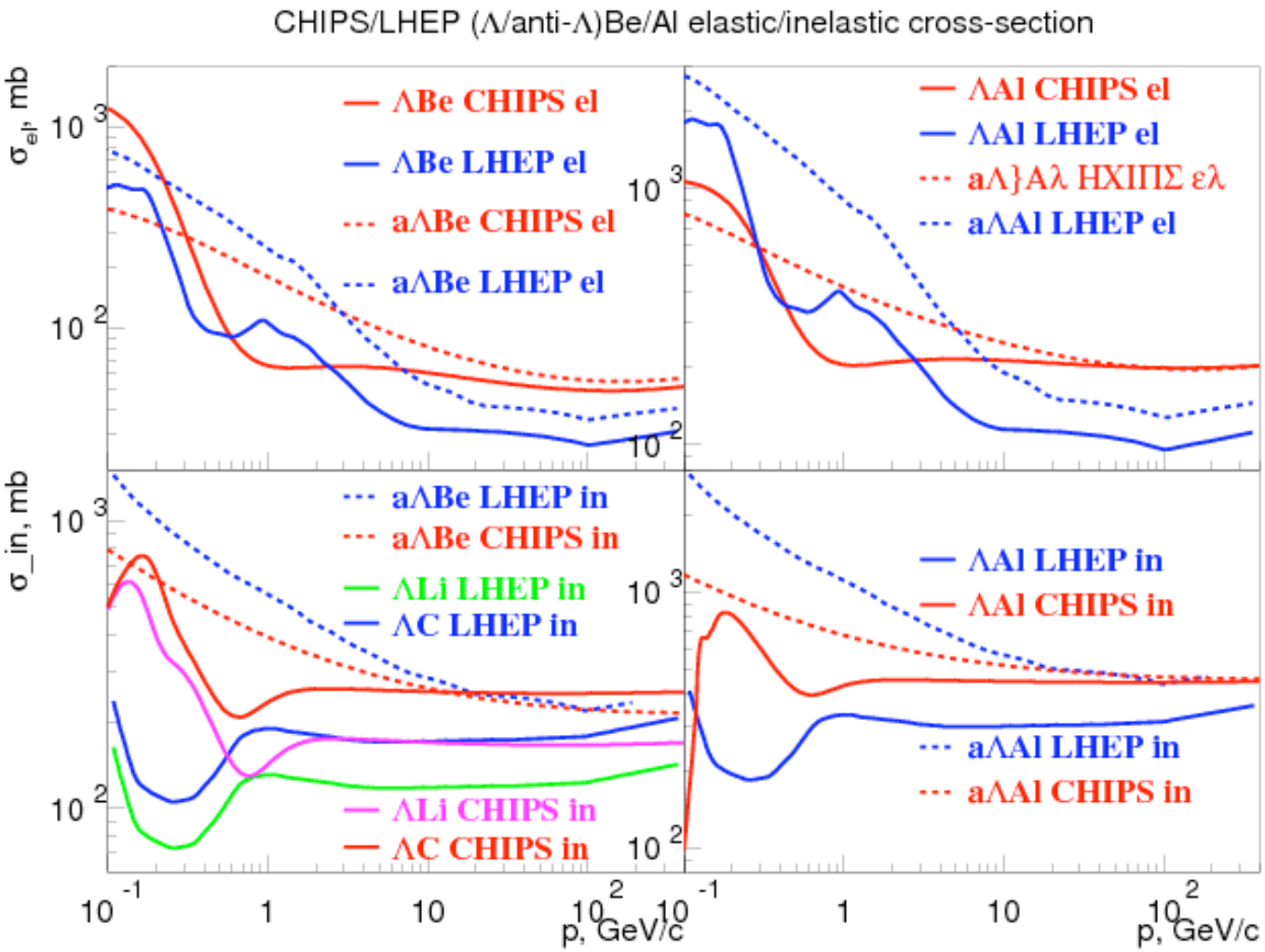
• In the MinBias comparison, the main differences are observed using EmOpt3 (w.r.t. the default EmOpt1) in the number of MCHits and E deposited in Si, although they are "smoothed" away in the digitization and reconstruction phase.

• Next step: test the new QGSP_BERT_CHIPS

• Comments are welcome

Backup slides

Λ(Λbar) on Be/Al - M. Kosov (Geant4)

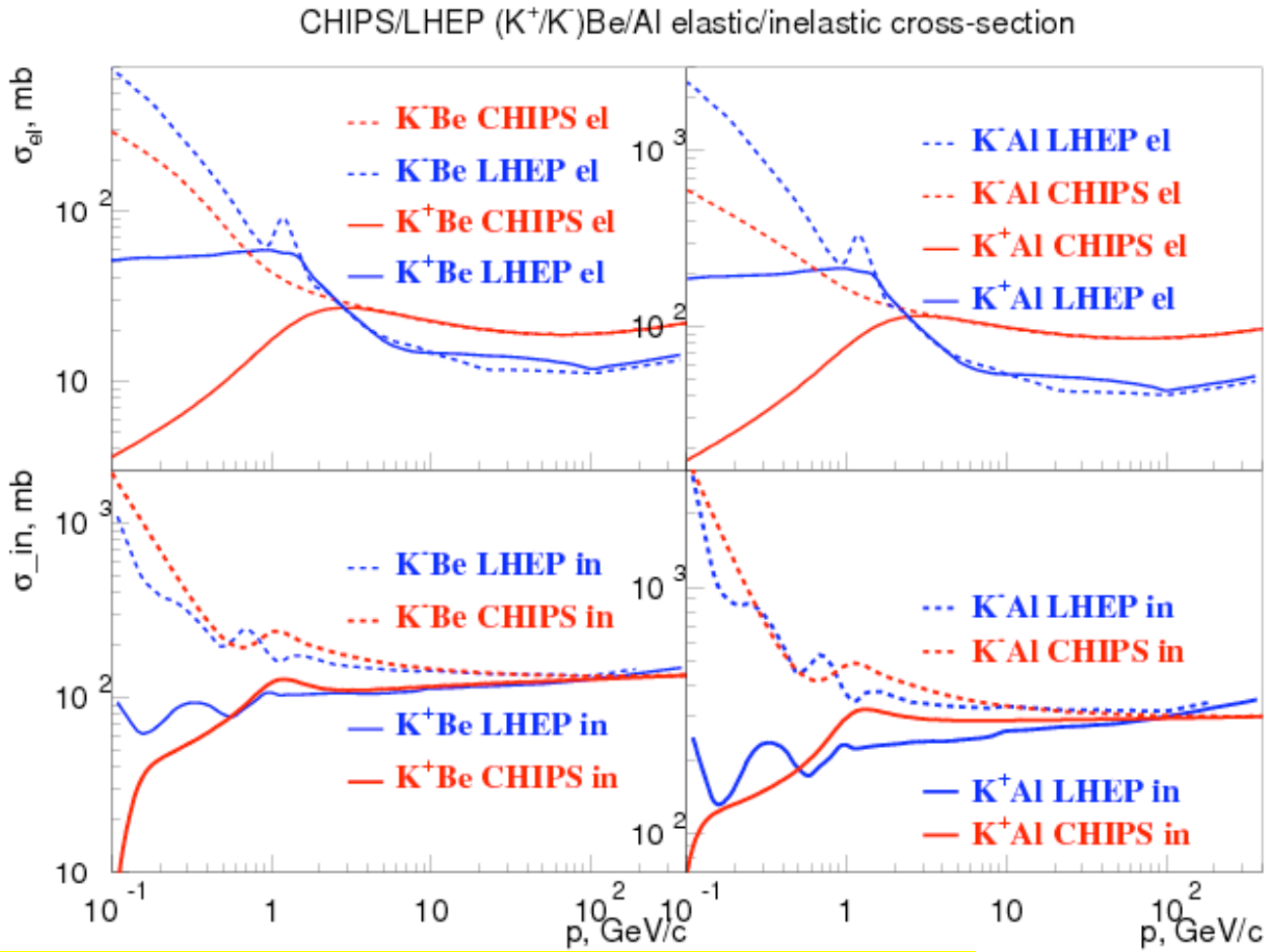


No differences for anti-proton and anti-lambda cross sections so dashed lines are the same for both pictures

LHEP: Systematic differences between particles/anti-particles cross sections at high energies. They should not exist.

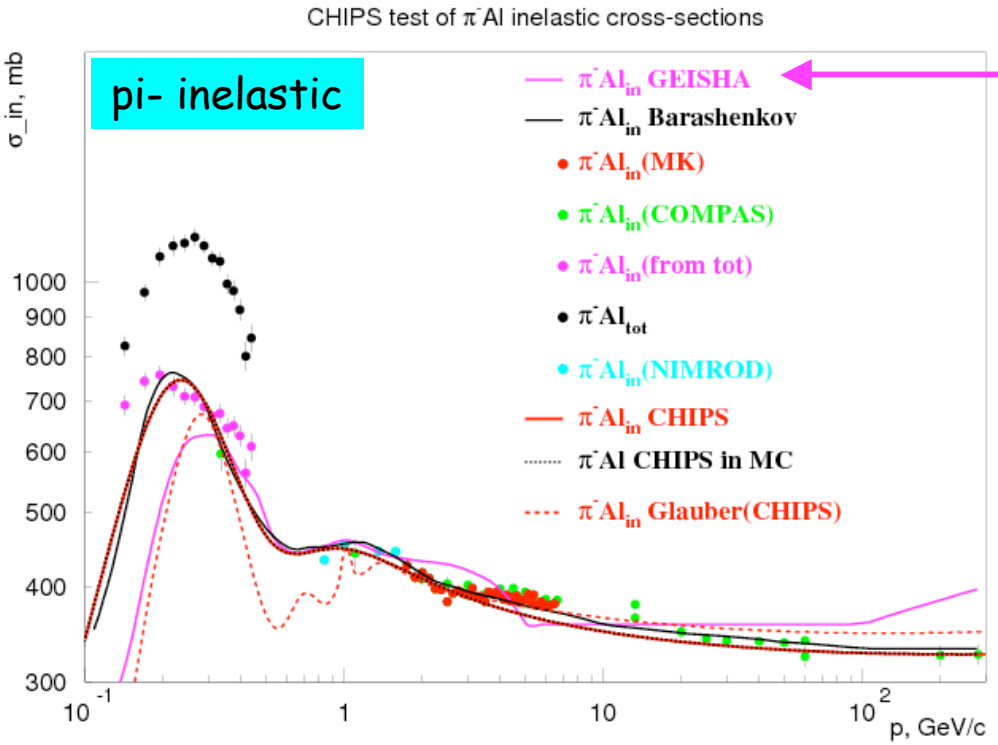
K+(K-) on Be/Al - M. Kosov (Geant4)

At high energies the LHEP fit both for elastic and inelastic cross section should give the same results for K+ and K-, but it does not.

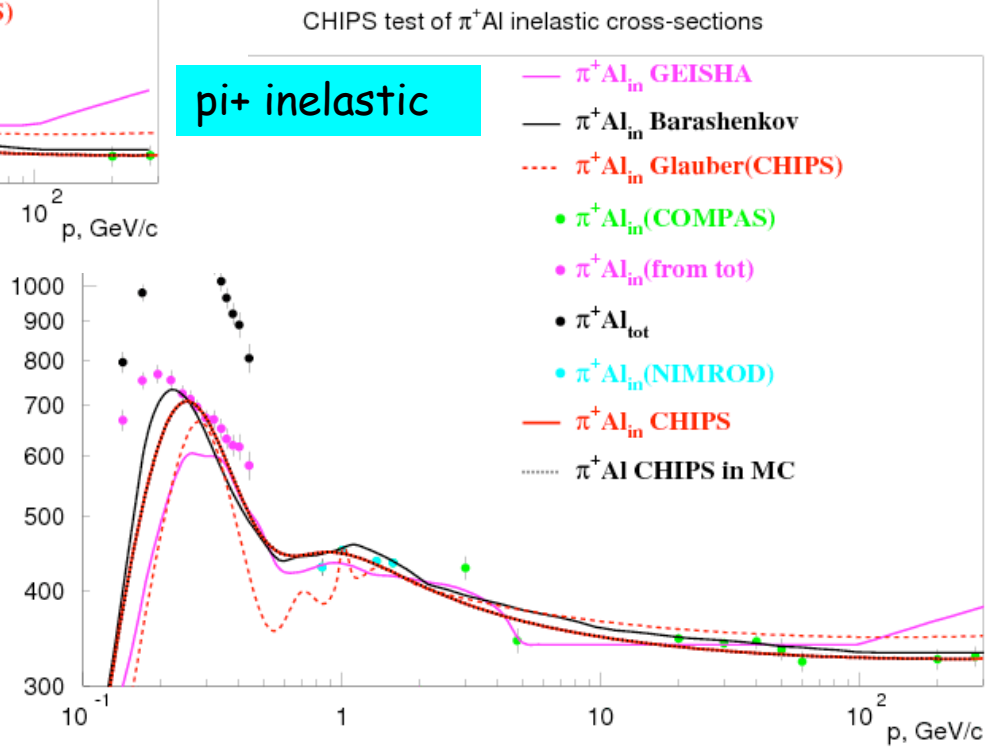


The K+ inelastic cross section does not drop to zero for zero energy (it should).

π+/- on Al (inelastic) - M. Kosov (Geant4)

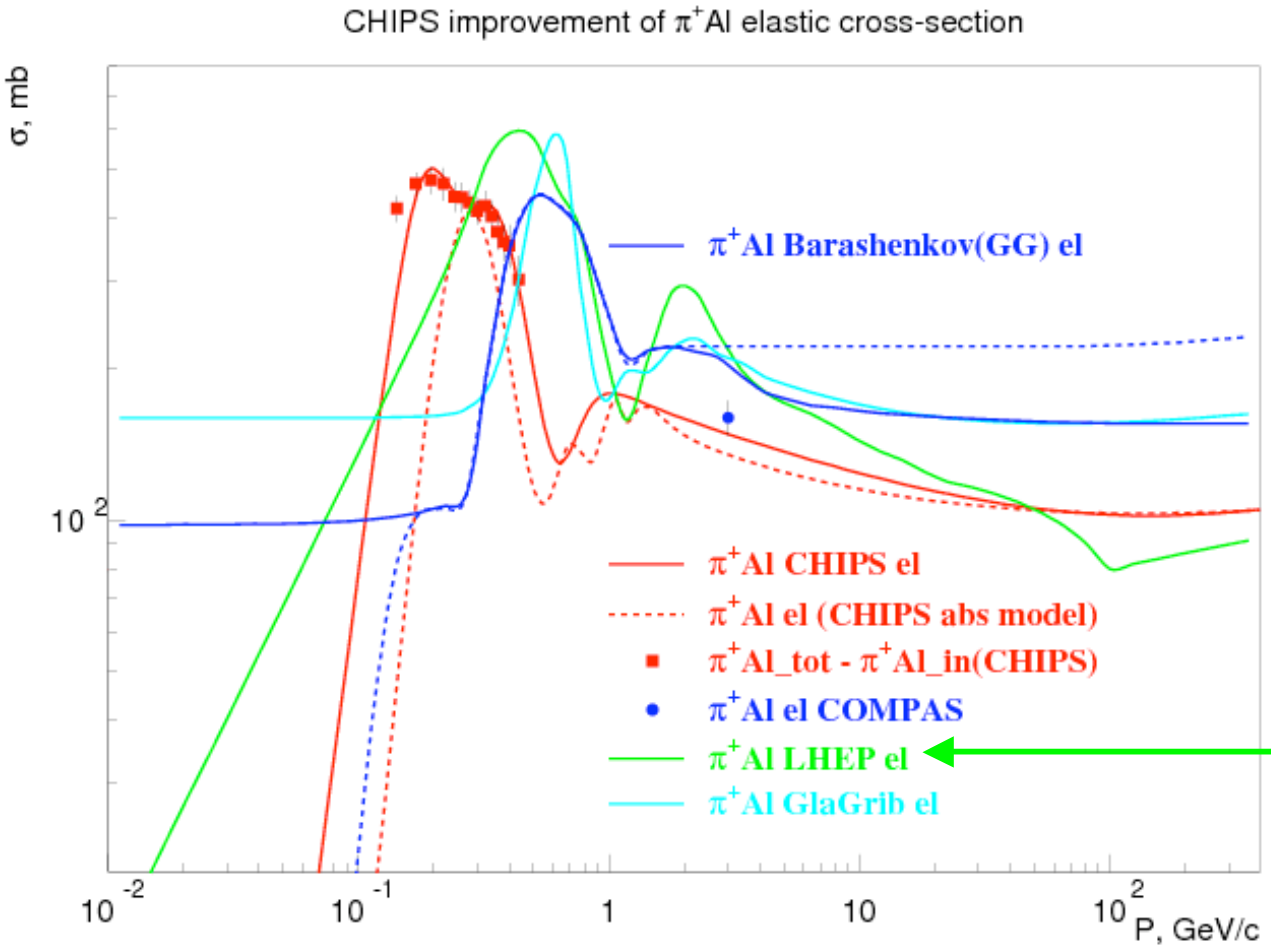


LHEP cross sections inherited from GEISHA (pink line)



07/07/2010

π+/- elastic on Al - M. Kosov (Geant4)



LHEP in GREEN

pi+/pi- elastic cross sections are the same (should be different at low energies). True for all Phys. Lists.

COMPAS database - p(pbar) on Al

- P Al -> INELASTIC

Plab (GeV/c)	σ (mb)	Err(stat.)
1.52	445.	10.
5.	445.	4.
9.	465.	4.
20.	446.	5.
30.	445.	5.
60.	455.	7.
200.	416.	12.
280.	415.	12.

- Pbar Al -> INELASTIC

Plab (GeV/c)	σ (mb)	Err(stat.)
1.45	617.	17.
6.65	558.	10.
13.3	536.	10.
25.	480.	9.
30.	457.	11.
60.	439.	13.
200.	435.	14.
280.	422.	15.

- P Al -> X

Plab (GeV/c)	σ (mb)	Err(stat.)
1.52	687.	22.
1.8	694.	27.
19.3	687.	10.
20.	687.	10.

- Pbar Al -> X

Plab (GeV/c)	σ(mb)	Err(stat.)
1.45	1034.	40.
1.8	1066.	40.

COMPAS database - p(pbar) on Be

• P Be -> INELASTIC

Plab (GeV/c)	σ (mb)	Err(stat.)
3.	236.	4.
5.	207.	3.
6.	208.	2.
7.	208.	3.
8.	213.	3.
9.	210.	3.
20.	208.	2.
30.	210.	3.
50.	210.	3.
60.	216.	2.
120.	176.	2.

• Pbar Be -> INELASTIC

Plab (GeV/c)	σ (mb)	Err(stat.)
6.65	296.	6.
13.3	275.	4.
20.	240.	10.
30.	235.	6.
40.	226.	7.
120.	190.	2.

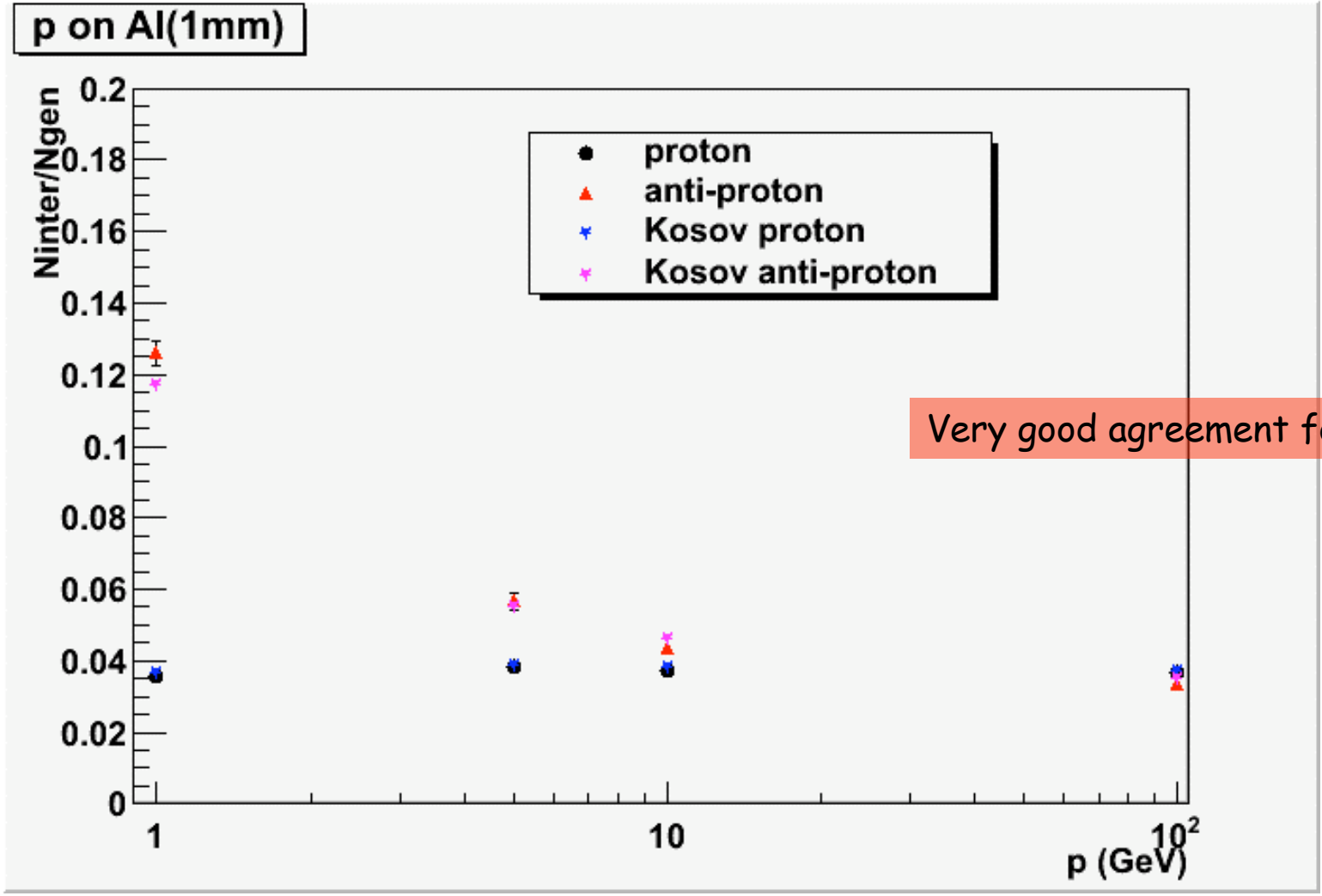
• Pbar Be -> X

Plab (GeV/c)	σ(mb)	Err(stat.)
1.09	484.	60.
1.34	425.	50.

• P Be -> X

Plab (GeV/c)	σ (mb)	Err(stat.)
1.11	254.	2.6
19.3	278.	4.
20.	278.	4.

p (pbar) on Al (1cm)

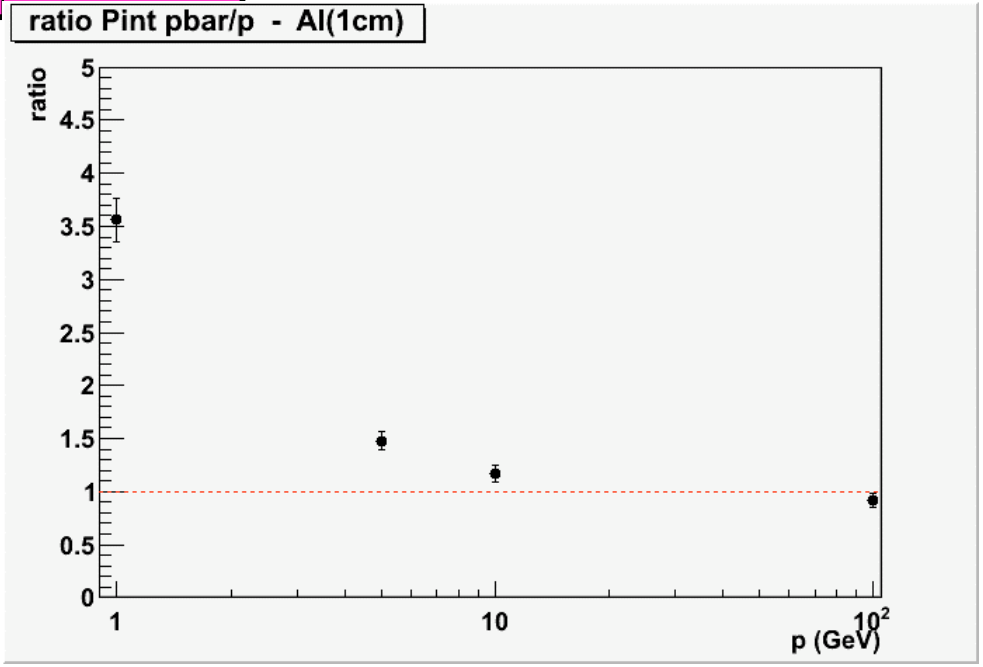


Very good agreement found

p (pbar) on Al (1cm)

PGUN	P (GeV/c)	Nint/Ngen	Err	Ratio pbar/p
p	1.	0.0354	0.0018	3.56±0.20
pbar	1.	0.126	0.0033	
p	5.	0.0382	0.0019	1.48±0.09
pbar	5.	0.0566	0.0023	
p	10.	0.0373	0.0019	1.17±0.08
pbar	10.	0.0438	0.0020	
p	100.	0.0365	0.0019	0.92±0.07
pbar	100.	0.0336	0.0018	

- Ngenerated = 10K (1 p per event)

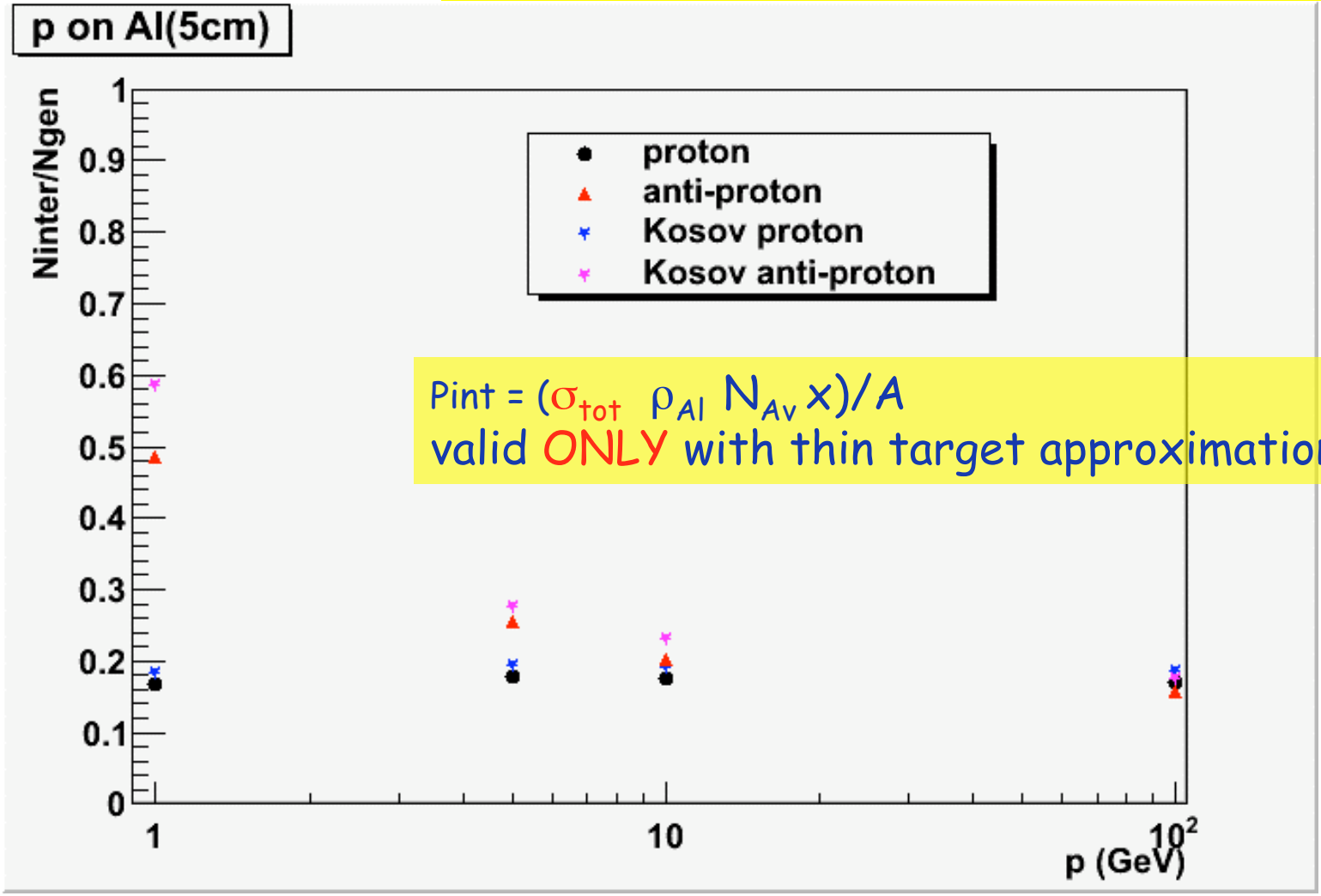


p (pbar) on Al (5cm)

Aluminium radiation length = 89mm

LHCb detector material budget (up to RICH2) ~0.6 X_0

-> Al thickness of 53.4mm



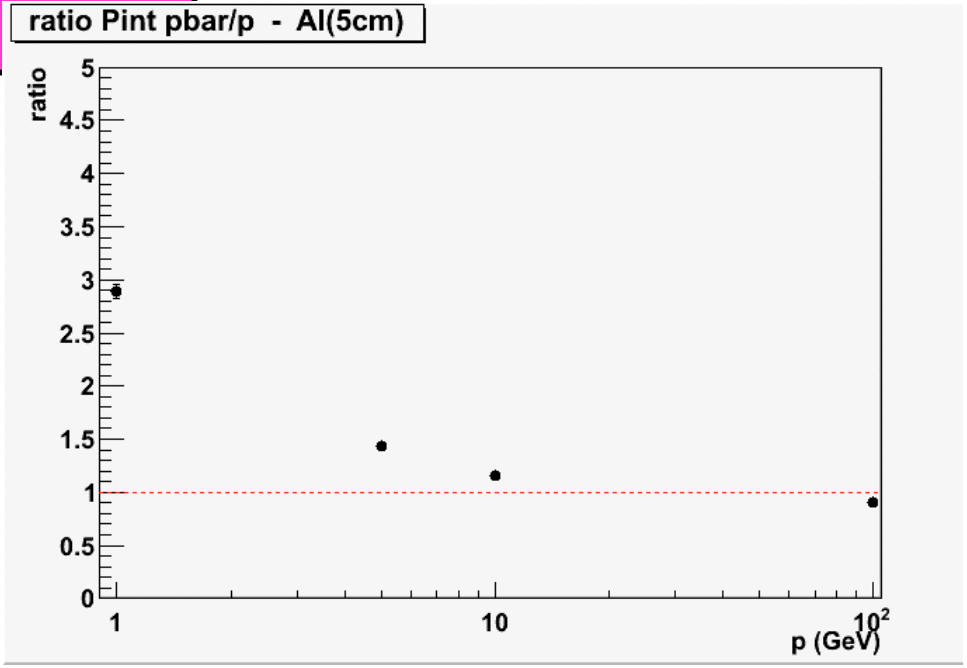
Pint = (σ_{tot} ρ_{Al} N_{Av} x)/A

valid ONLY with thin target approximation (P_{int}<<1)

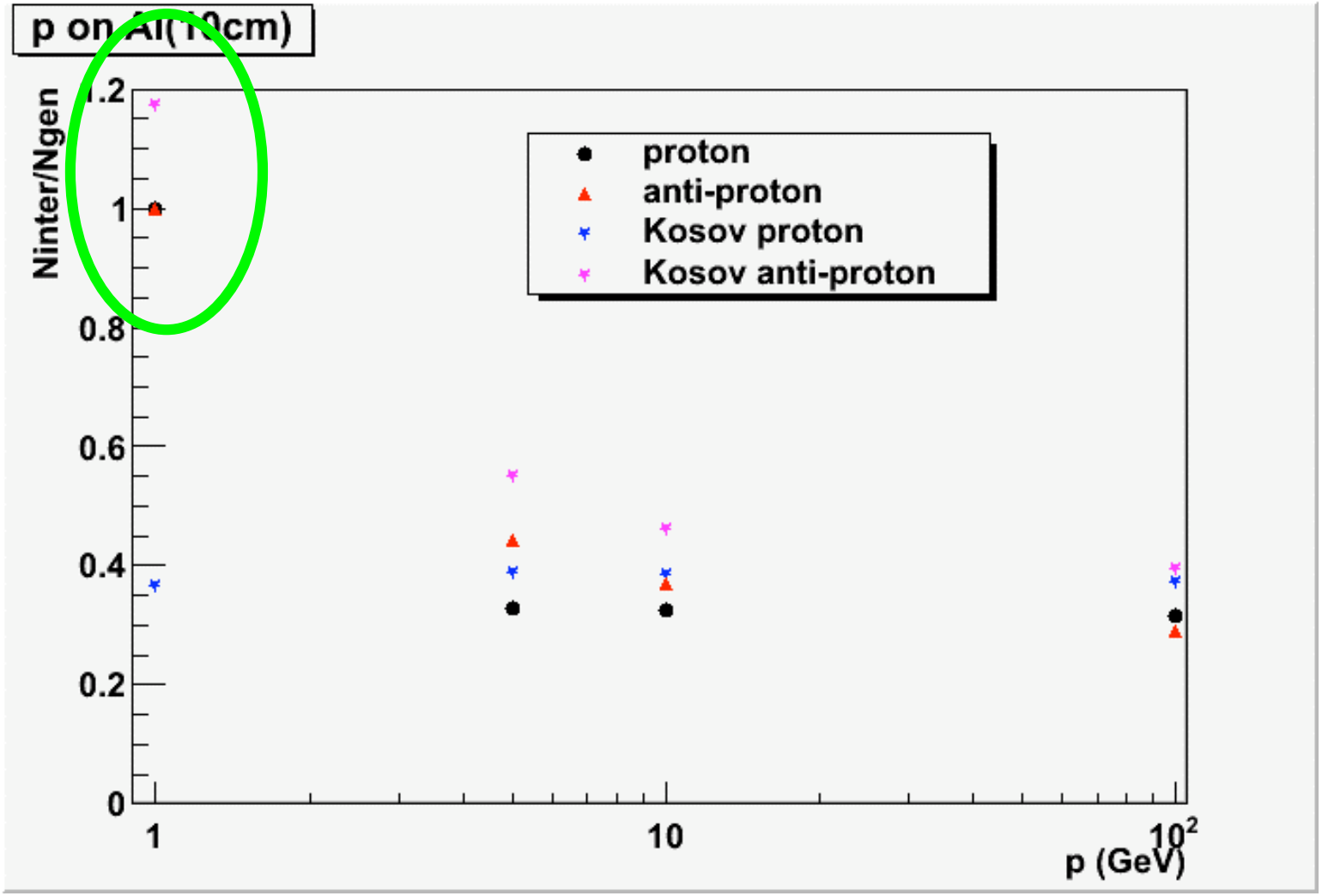
p (pbar) on Al (5cm)

PGUN	P (GeV/c)	Nint/Ngen	Err	Ratio pbar/p
p	1.	0.1679	0.0037	2.89±0.07
pbar	1.	0.4851	0.0050	
p	5.	0.1778	0.0038	1.43±0.04
pbar	5.	0.2548	0.0044	
p	10.	0.1746	0.0038	1.16±0.03
pbar	10.	0.2029	0.0040	
p	100.	0.1711	0.0038	0.91±0.03
pbar	100.	0.1565	0.0036	

- Ngenerated = 10K (1 p per event)



p (pbar) on Al (10cm)

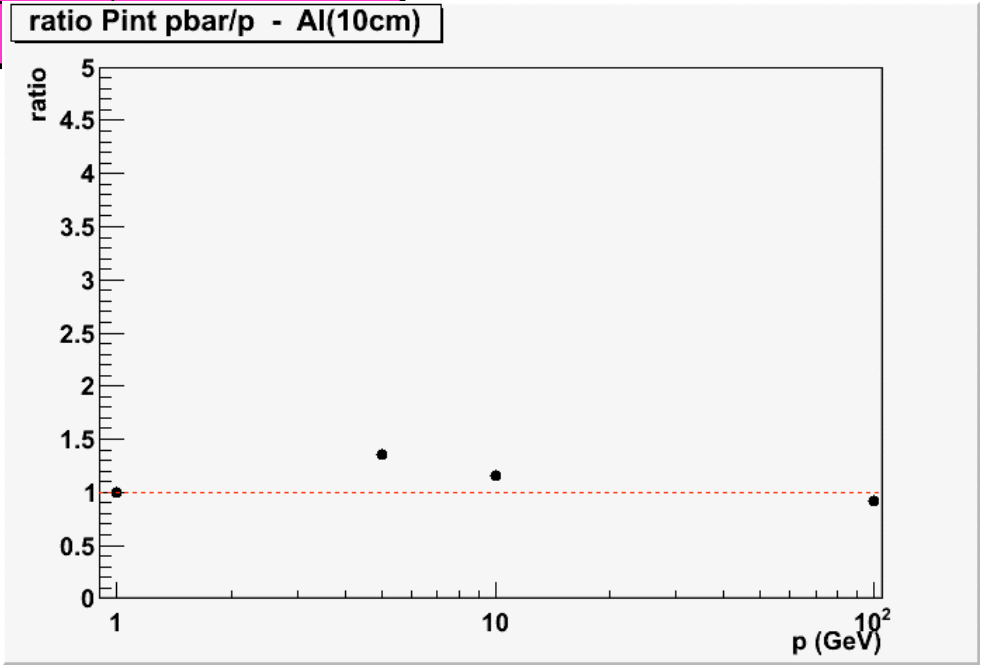


$P_{int} = (\sigma_{tot}\ \rho_{Al}\ N_{Av}\ x)/A$

valid ONLY with thin target approximation ($P_{int} << 1$)

p (pbar) on Al (10cm)

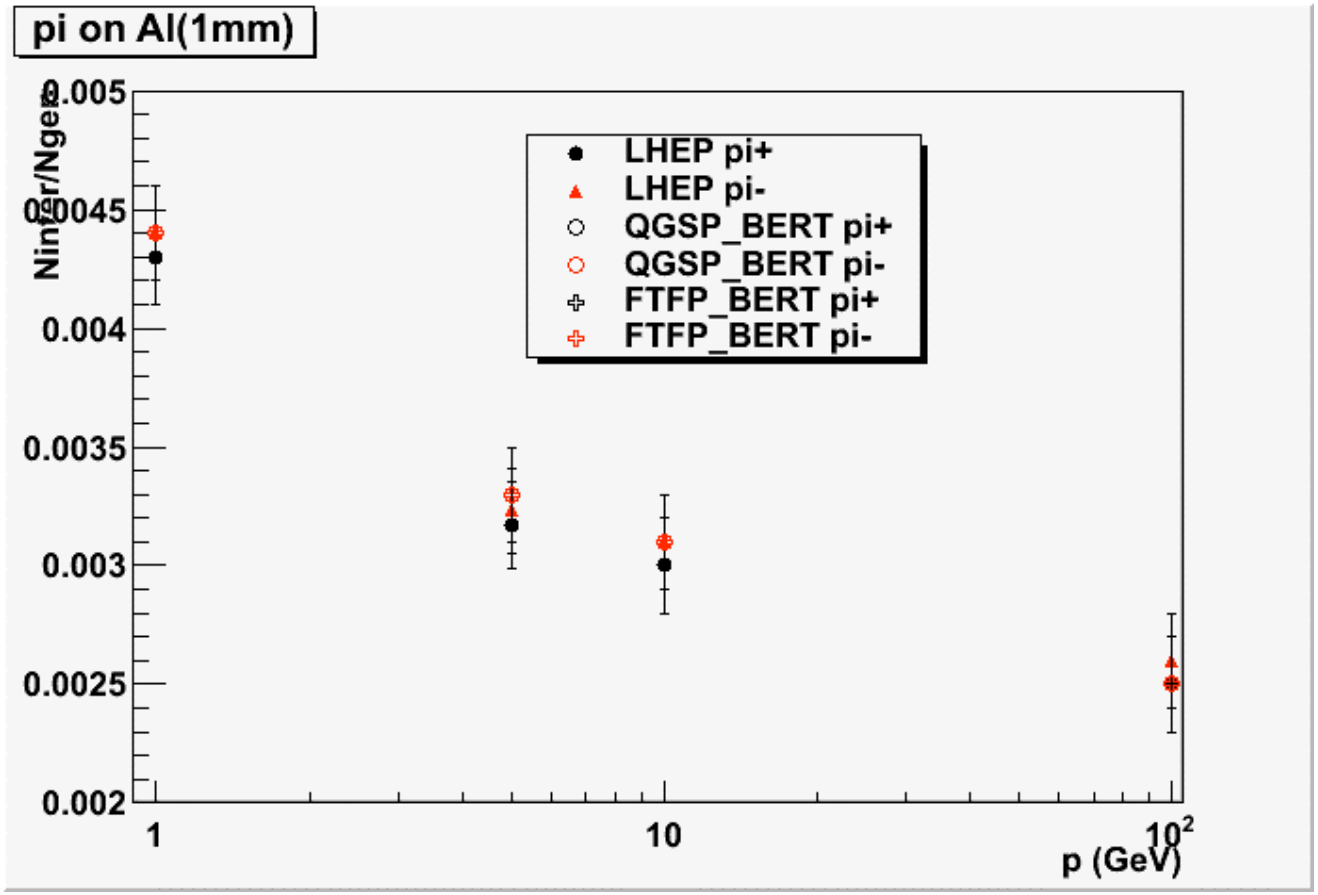
PGUN	P (GeV/c)	Nint/Ngen	Err	Ratio pbar/p
p	1.	1.	0.	1.±0.
pbar	1.	1.	0.	
p	5.	0.3274	0.0047	1.35±0.02
pbar	5.	0.4437	0.0050	
p	10.	0.3236	0.0047	1.15±0.02
pbar	10.	0.371	0.0048	
p	100.	0.3147	0.0046	0.92±0.02
pbar	100.	0.2906	0.0045	



- Ngenerated = 10K (1 p per event)

Comparison P_{int} for different Phys Lists

- P_{int}(K+/-) and P_{int}(p/pbar) are the same for the 3 PLs considered
- P_{int}(pi+/-) for LHEP is slightly different from P_{int}(pi+/-) QGSP_BERT (FTFP_BERT). The difference is of few%
- P_{int}(pi+) = P_{int}(pi-) in QGSP_BERT (FTFP_BERT)



p (pbar) on Al (1mm)

- Ngenerated = 10K (1 p per event)

PGUN	P (GeV/c)	Nint(LHEP)	Nint(QGSPBERT)	Nint(FTFPBERT)	<Mult> (LHEP)	<Mult> (QGSPBERT)	<Mult> (FTFPBERT)
p	1.	38	39	39	11.61	9.08	9.08
pbar	1.	143	143	143	12.04	12.04	12.04
p	5.	37	37	37	12.62	13.42	11.96
pbar	5.	62	62	62	12.65	12.65	12.65
p	10.	37	37	37	8.25	17.46	11.88
pbar	10.	46	46	46	9.26	9.26	9.26
p	13.	37	37	37	8.96	9.71	12.25
pbar	13.	43	43	43	11.03	11.03	11.03
p	100.	35	35	35	13.29	21.79	18.12
pbar	100.	28	28	28	17.17	17.17	17.17

K+(K-) on Al (1mm)

- Ngenerated = 10K (1 k per event)

PGUN	P (GeV/c)	Nint(LHEP)	Nint(QGSPBERT)	Nint(FTFPBERT)	<Mult> (LHEP)	<Mult> (QGSPBERT)	<Mult> (FTFPBERT)
K+	1.	23	23	23	11.9	7.6	7.6
K-	1.	47	47	47	12.68	12.46	12.46
K+	5.	16	16	16	14.43	16.57	11.07
K-	5.	24	24	24	16.05	17.27	12.82
K+	10.	18	18	18	10.82	15.88	11.88
K-	10.	23	23	23	10.55	18.77	12.86
K+	13.	19	19	19	11.5	9.5	11.94
K-	13.	23	23	23	11.36	10.23	11.77
K+	100.	20	20	20	20.2	15.55	17.15
K-	100.	21	21	21	18.67	15.0	18.24

VELO: E deposited in Si