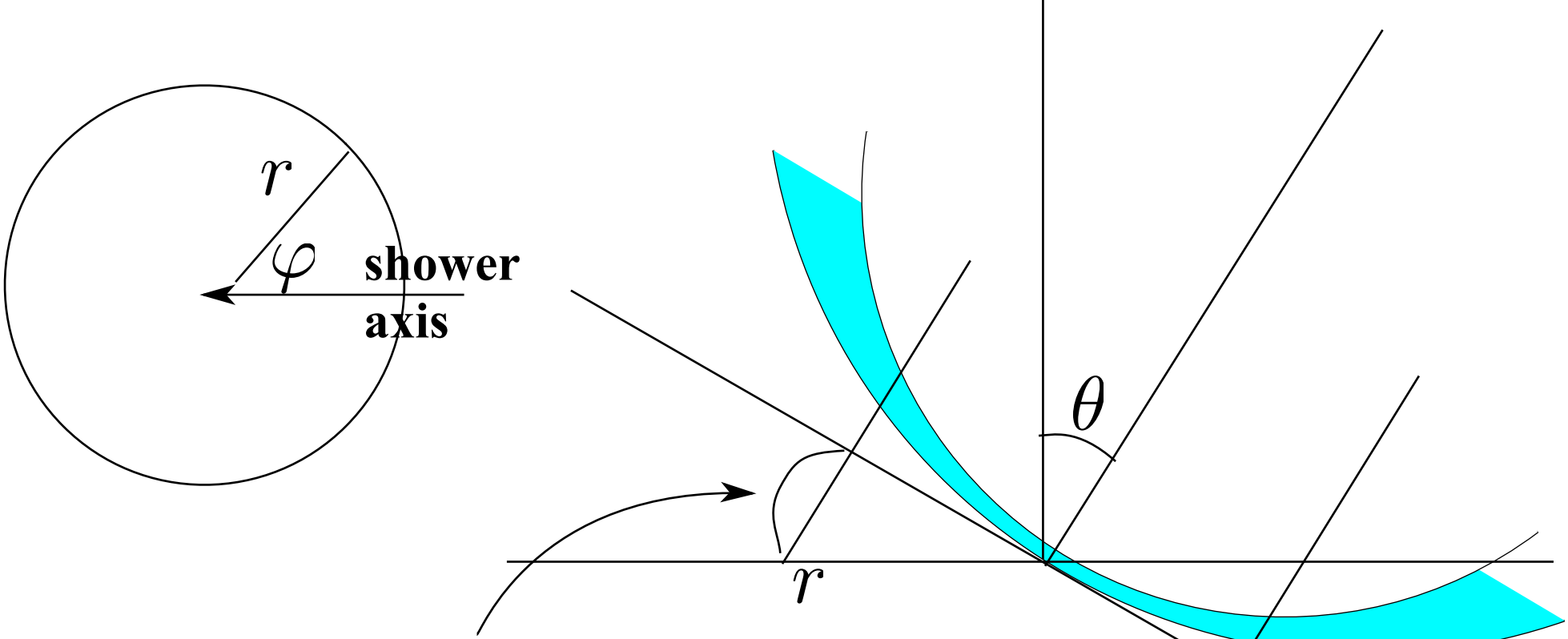


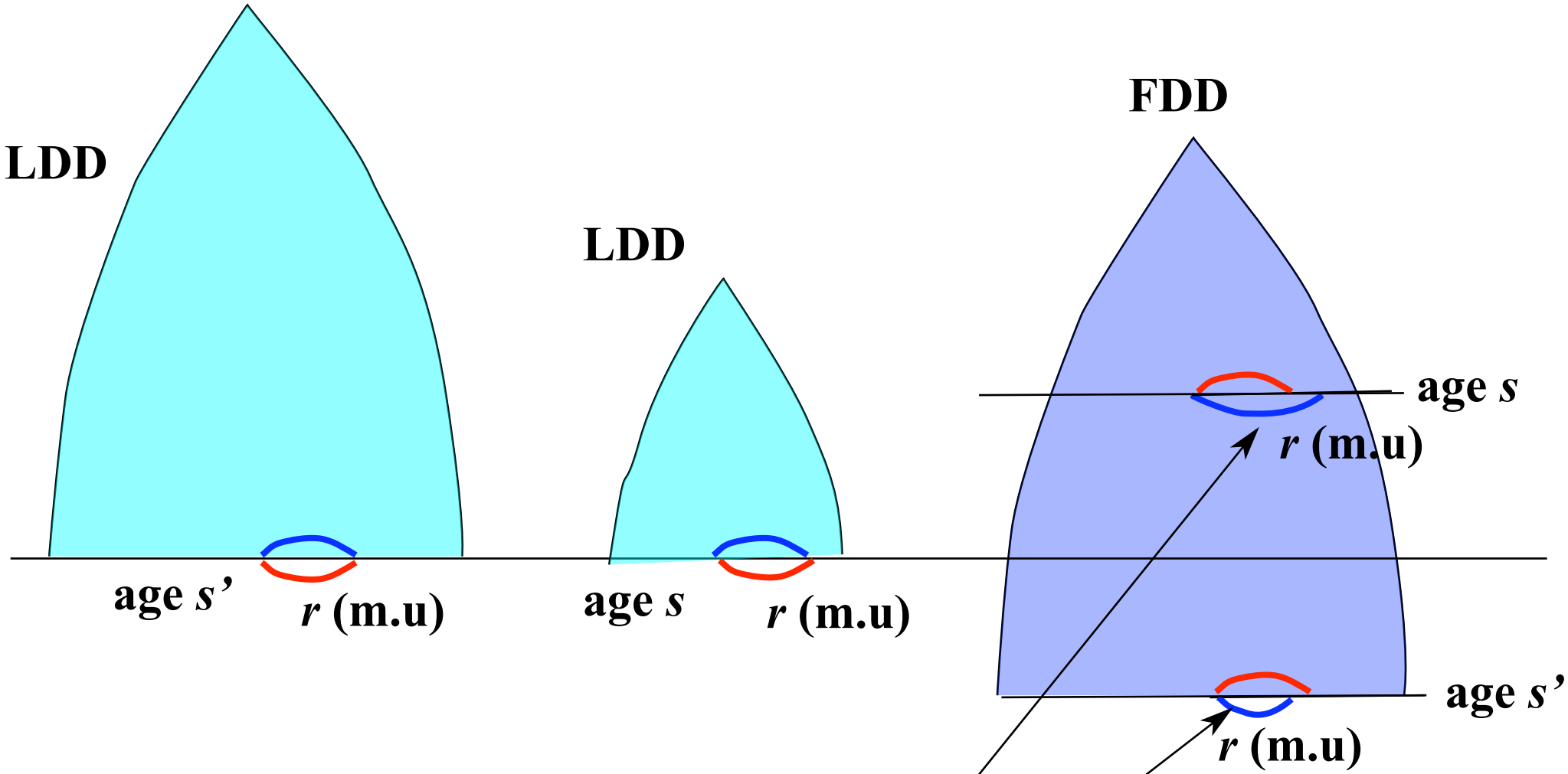
$$d = r\cos\varphi\sin\theta$$

Reduced arrival time: time at (r, φ) is transformed to

$$t \leftarrow t + \Delta t$$

$$\Delta t = r(\cos\varphi + 1)\sin\theta/c$$

so that t is everywhere positive. Here r is in real length and c the light velocity. Δt is adjusted so that time t at $\varphi = 0$ corresponds to the one at $\varphi = 180°$. That is, $\Delta t = 2d/c$ $(\varphi = 0))$, $d/c(\varphi = 90°)$, 0 $(\varphi = 180°)$



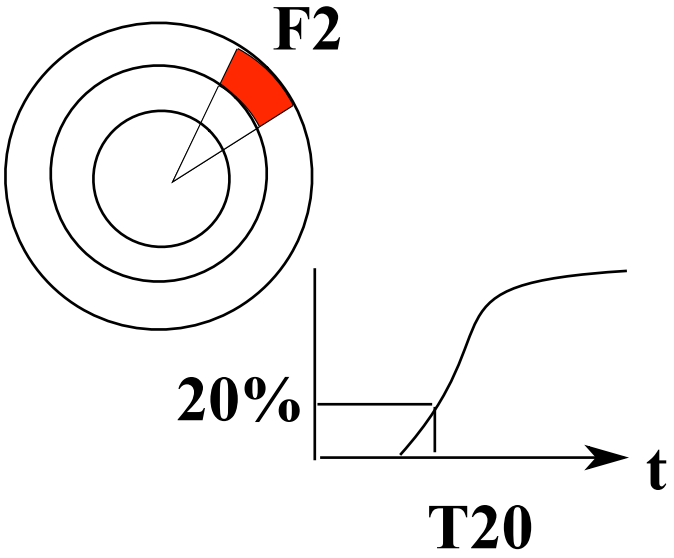
particle properties (energy, angle, arrival time...) of LDD at observation depth at (r, φ) must be extracted from FDD at the same age s and same (r, φ) of the LDD. Here, r is in m.u. However, arrival time of FDD at r dose not coincide with LDD's. As far as the timing is concerned, we should see it at the same real length (red in Fig.) So we have to invent correction method of timing at r of FDD.

Geometrical scaling:

When we look for FDD information, we see r (in m.u see previous page). The time at r in LDD is supposed to be the time in FDD at r*(muLDD)/(muFDD), since the distance in real length is the same.

To confirm this:

In each web sector, we construct normalized arrival time distribution.



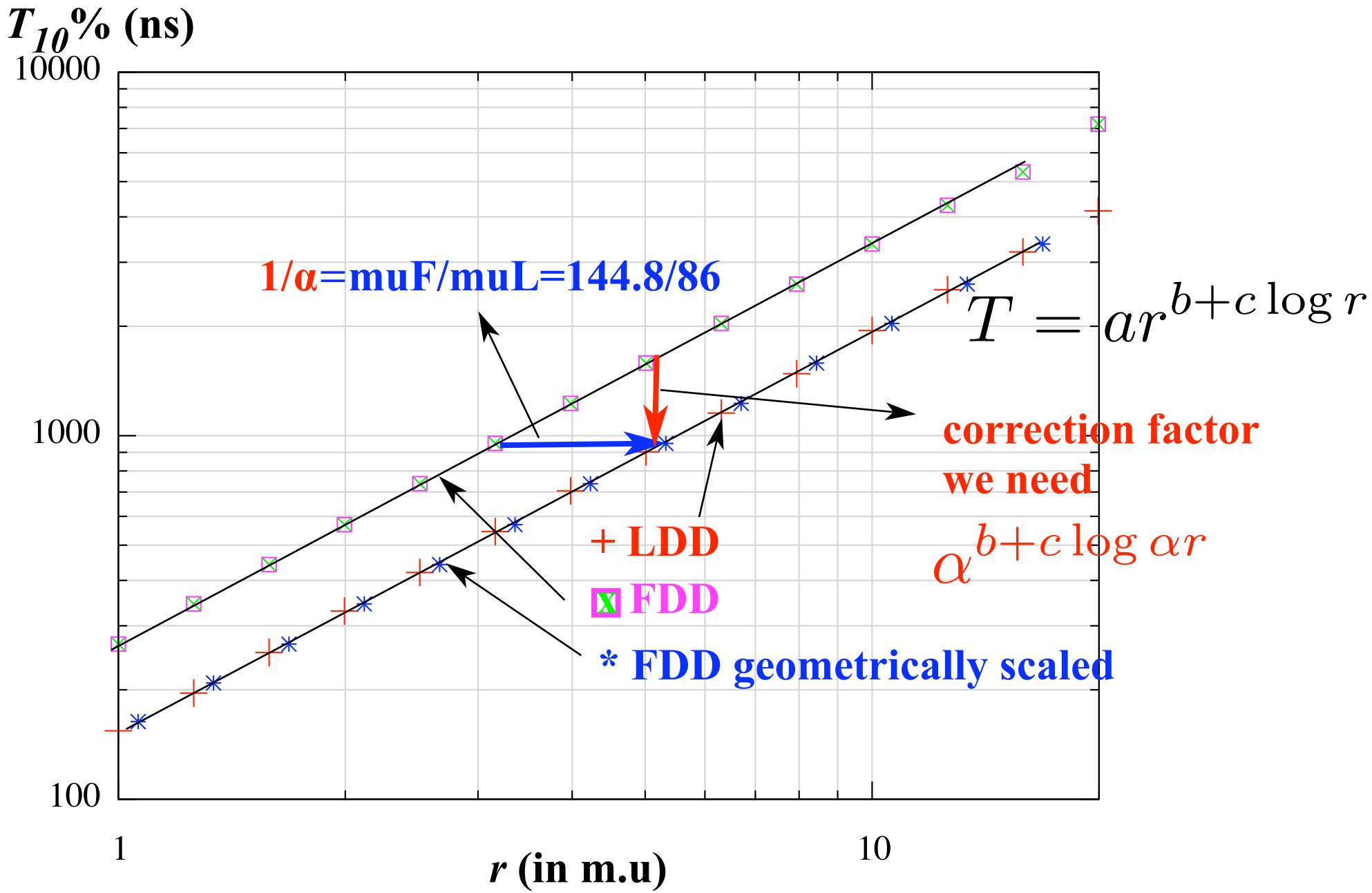
We plot T10, T50 etc as a function of *r* (in m.u) at a given Fai (F1, F2 etc)

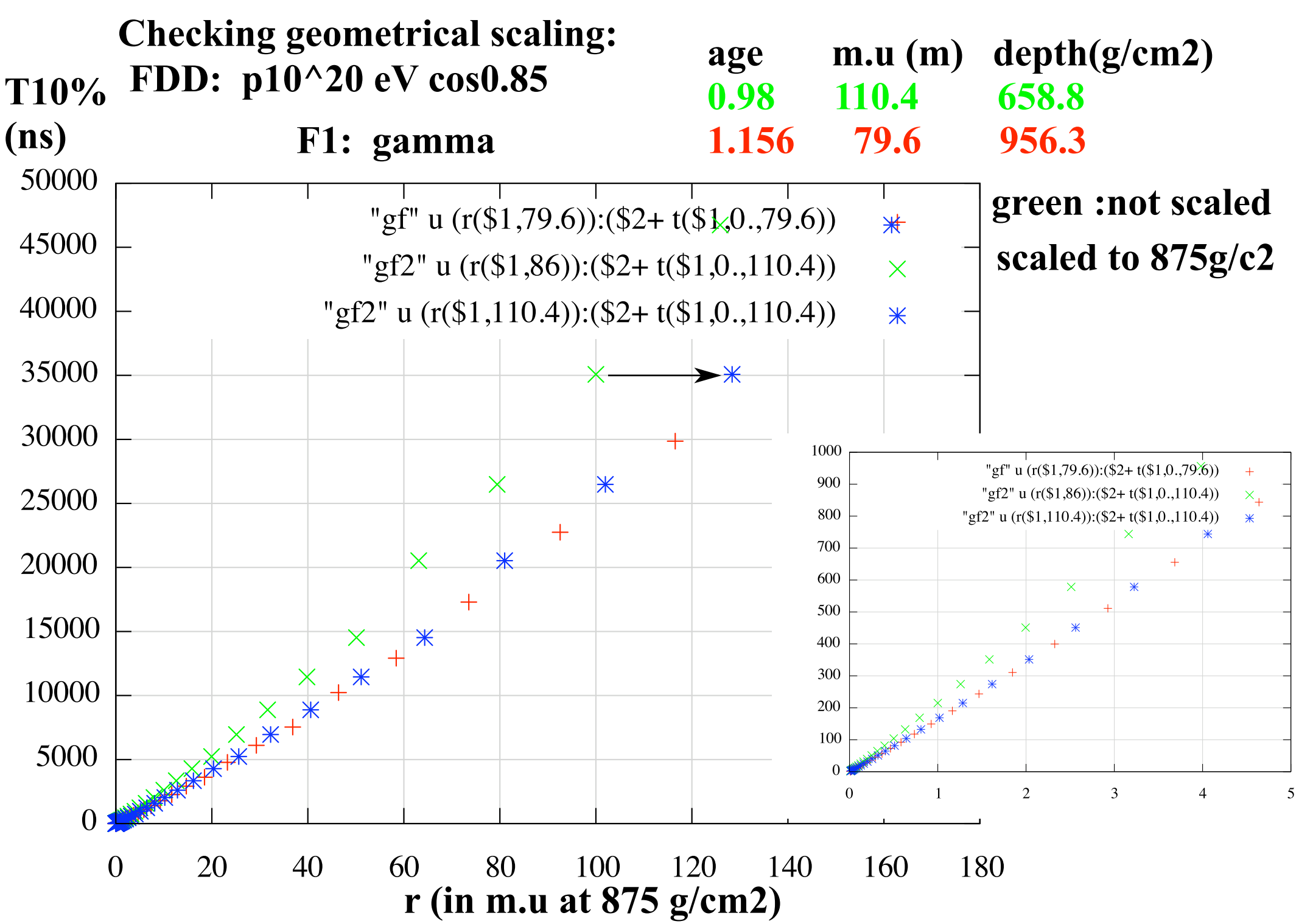
In plot, time is reduced time.

Geometrical scaling to 875 g/cm^2 means that as the time at *r* at depth *d*, we employ time *T* at distance

$$r\frac{mu_{875}}{mu_d}$$

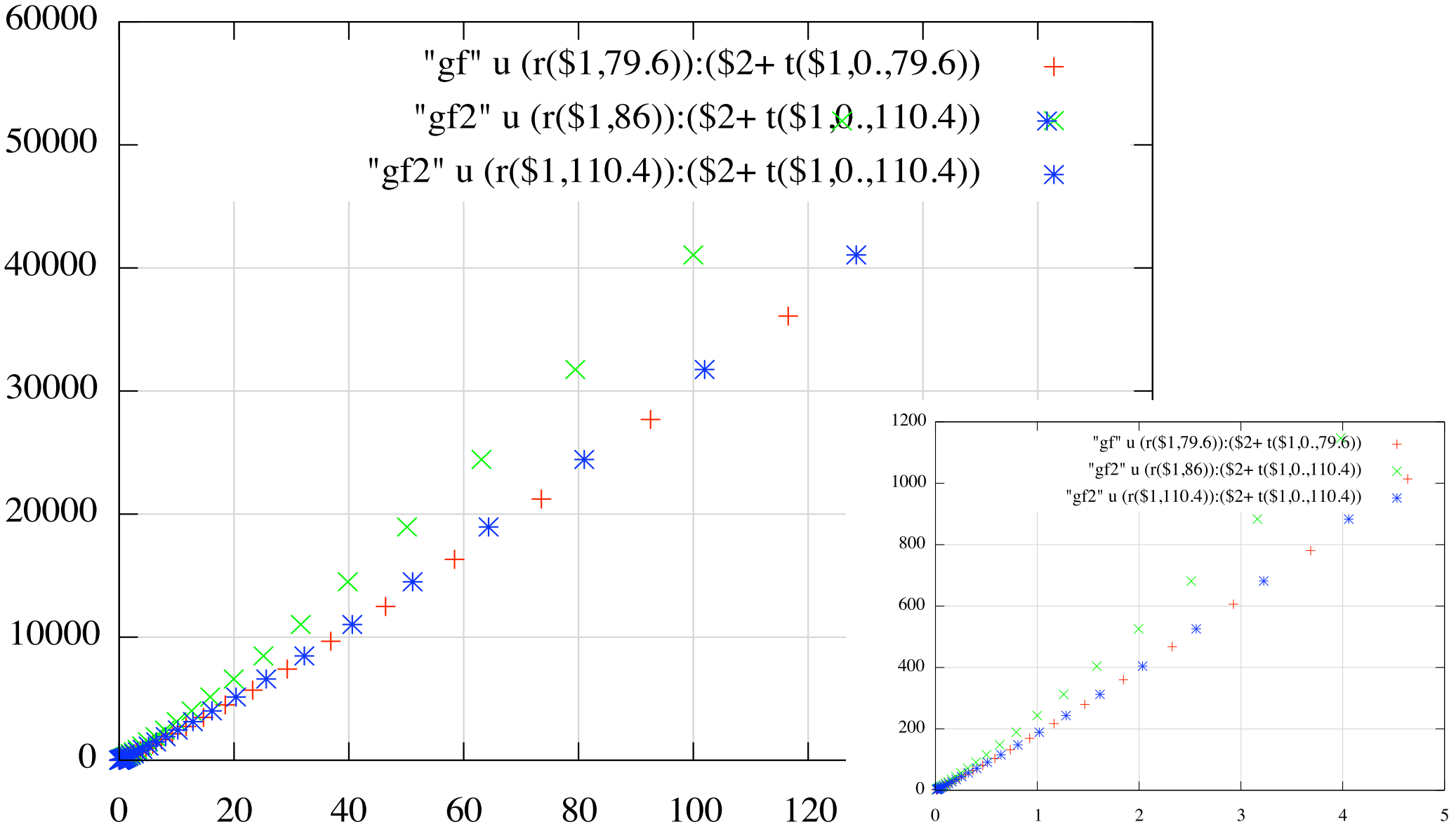
One extreme example: LDD first col. depth =382 g/cm^2




Checking geometrical scaling:
FDD: p10^20 eV cos0.85
F1: gamma
age
m.u (m)
depth(g/cm2)
0.98
110.4
658.8
1.156
79.6
956.3
T10%
(ns)
green :not scaled
scaled to 875g/c2
"gf" u (r($1,79.6)):($2+ t($1,0.,79.6))
"gf2" u (r($1,86)):($2+ t($1,0.,110.4))
"gf2" u (r($1,110.4)):($2+ t($1,0.,110.4))
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
20
40
60
80
100
120
140
160
180
r (in m.u at 875 g/cm2)
1000
900
800
700
600
500
400
300
200
100
0
0
1
2
3
4
5

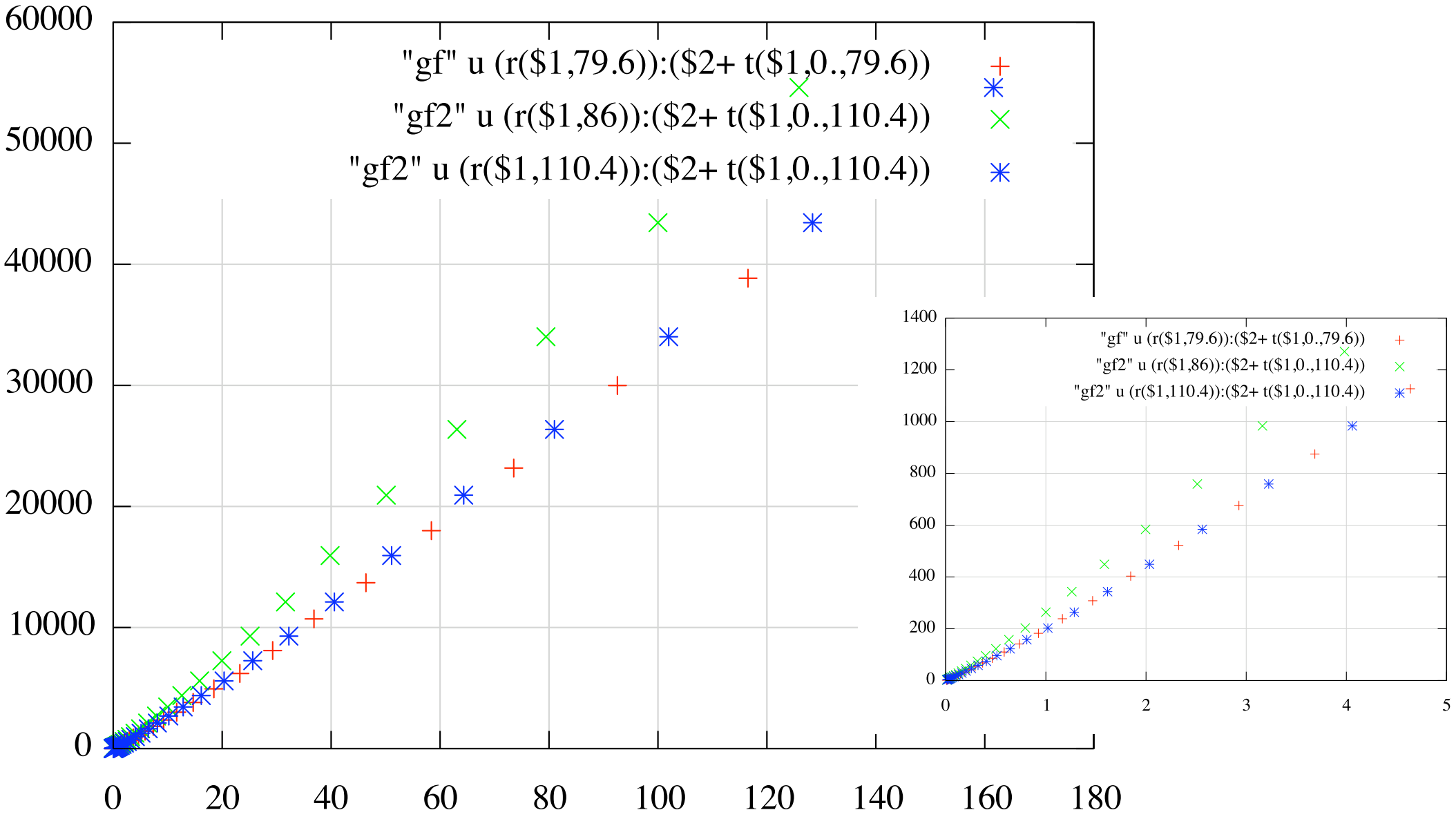
ibid

T50% **F1: gamma**



ibid

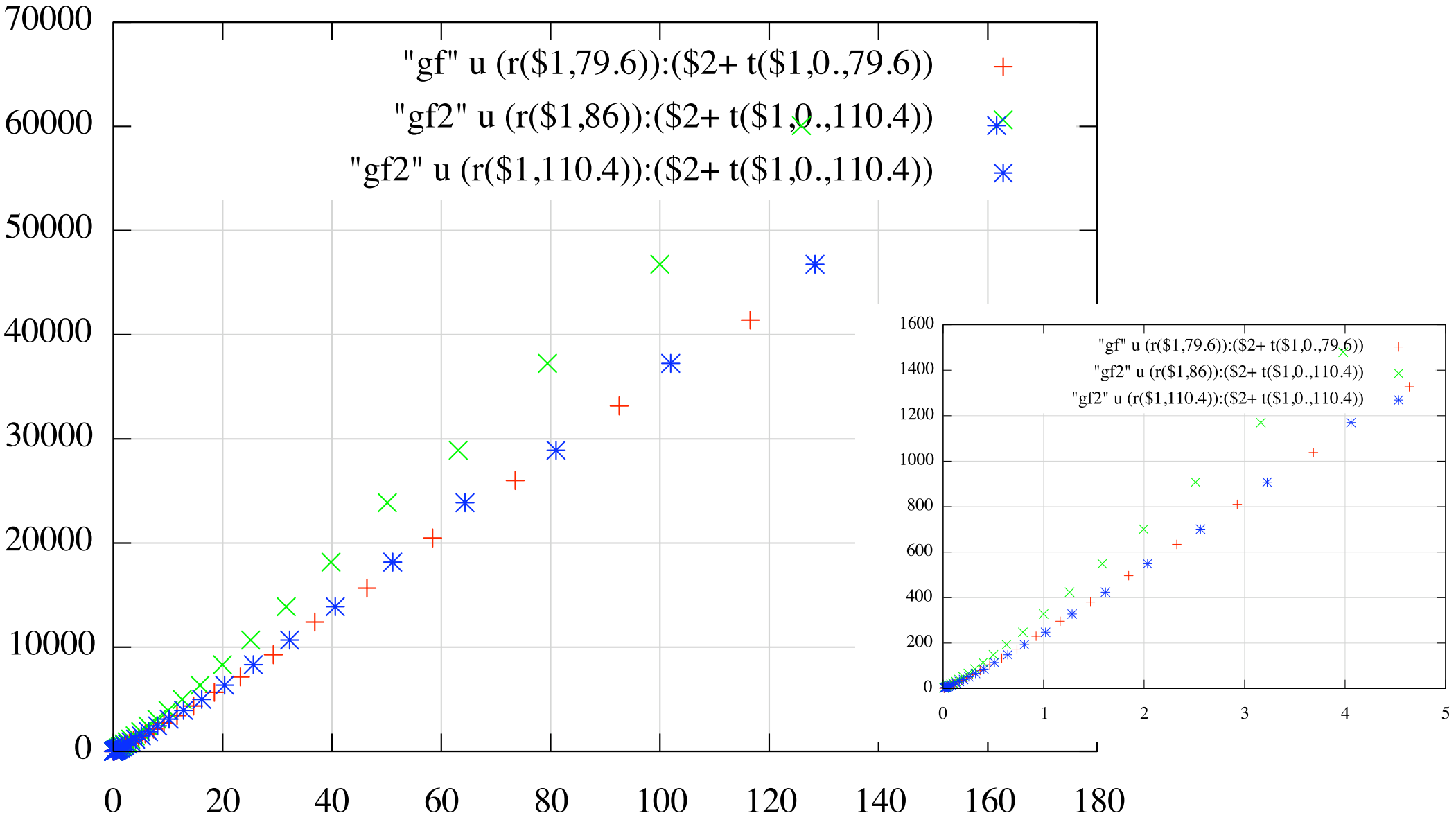
T70% **F7: gamma**

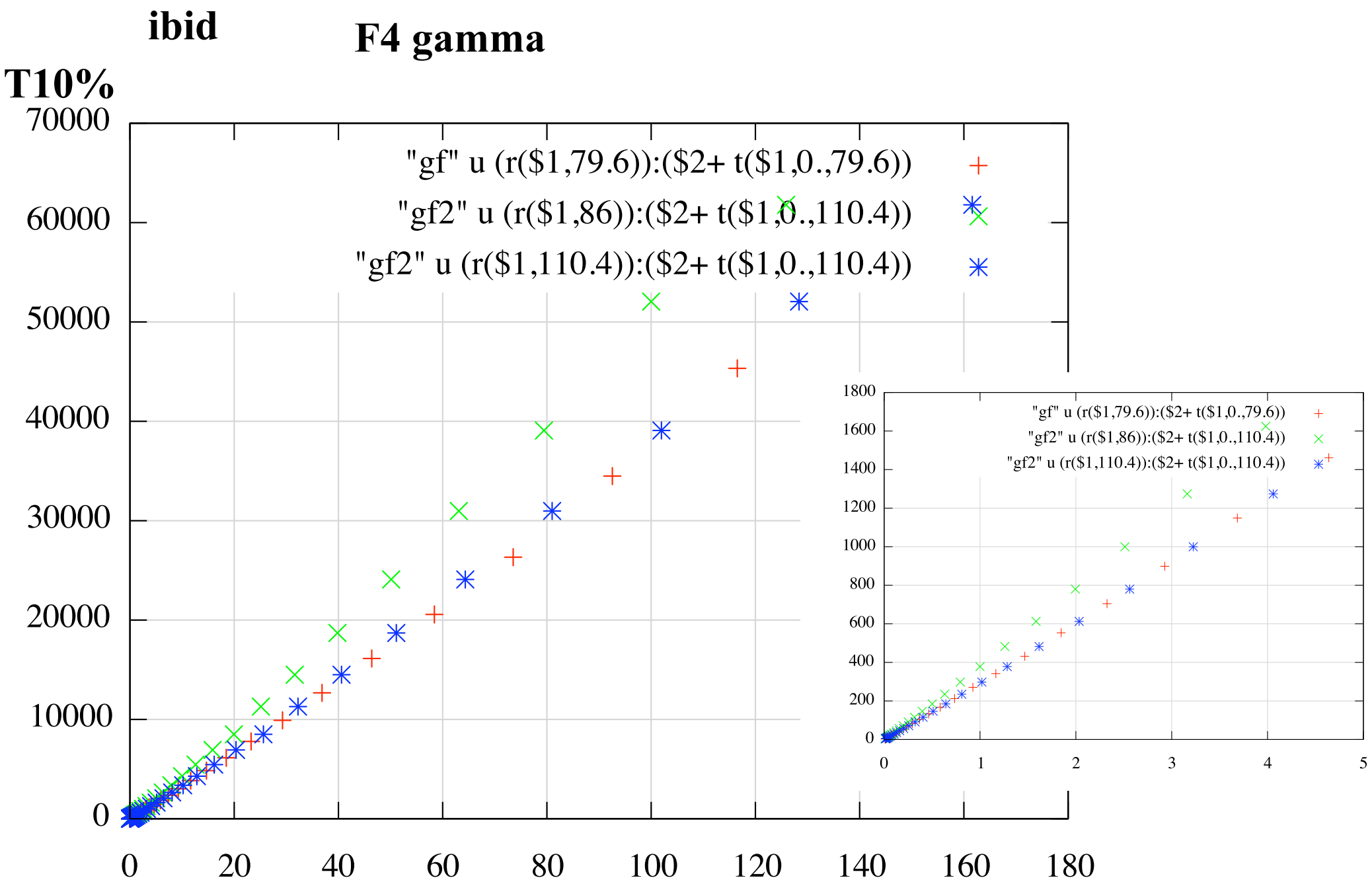


ibid

F1: gamma

T90%

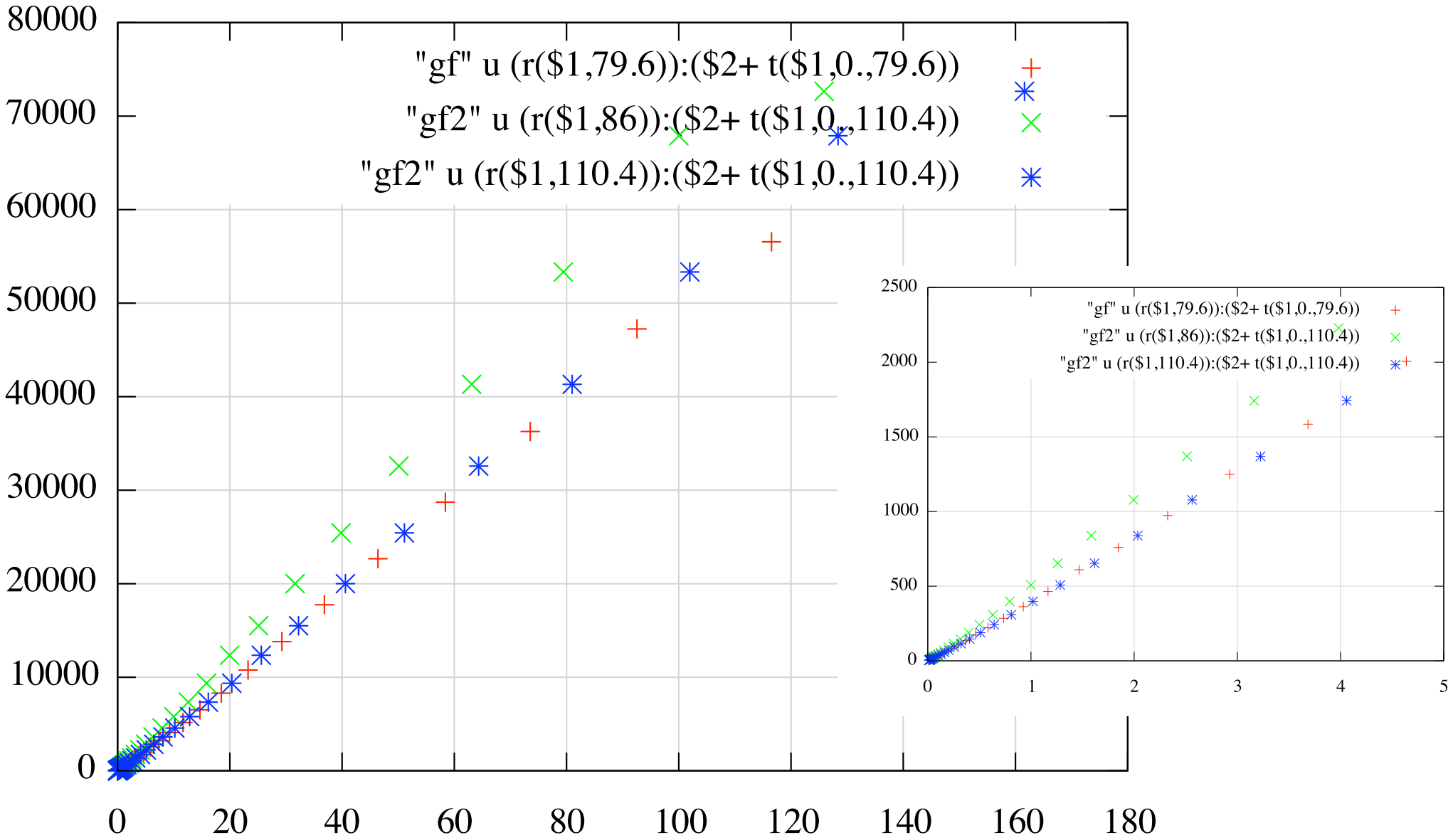



ibid
F4 gamma
T10%
"gf" u (r($1,79.6)):($2+ t($1,0.,79.6))
"gf2" u (r($1,86)):($2+ t($1,0.,110.4))
"gf2" u (r($1,110.4)):($2+ t($1,0.,110.4))
70000
60000
50000
40000
30000
20000
10000
0
0
20
40
60
80
100
120
140
160
180
1800
1600
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5

ibid

F4: gamma

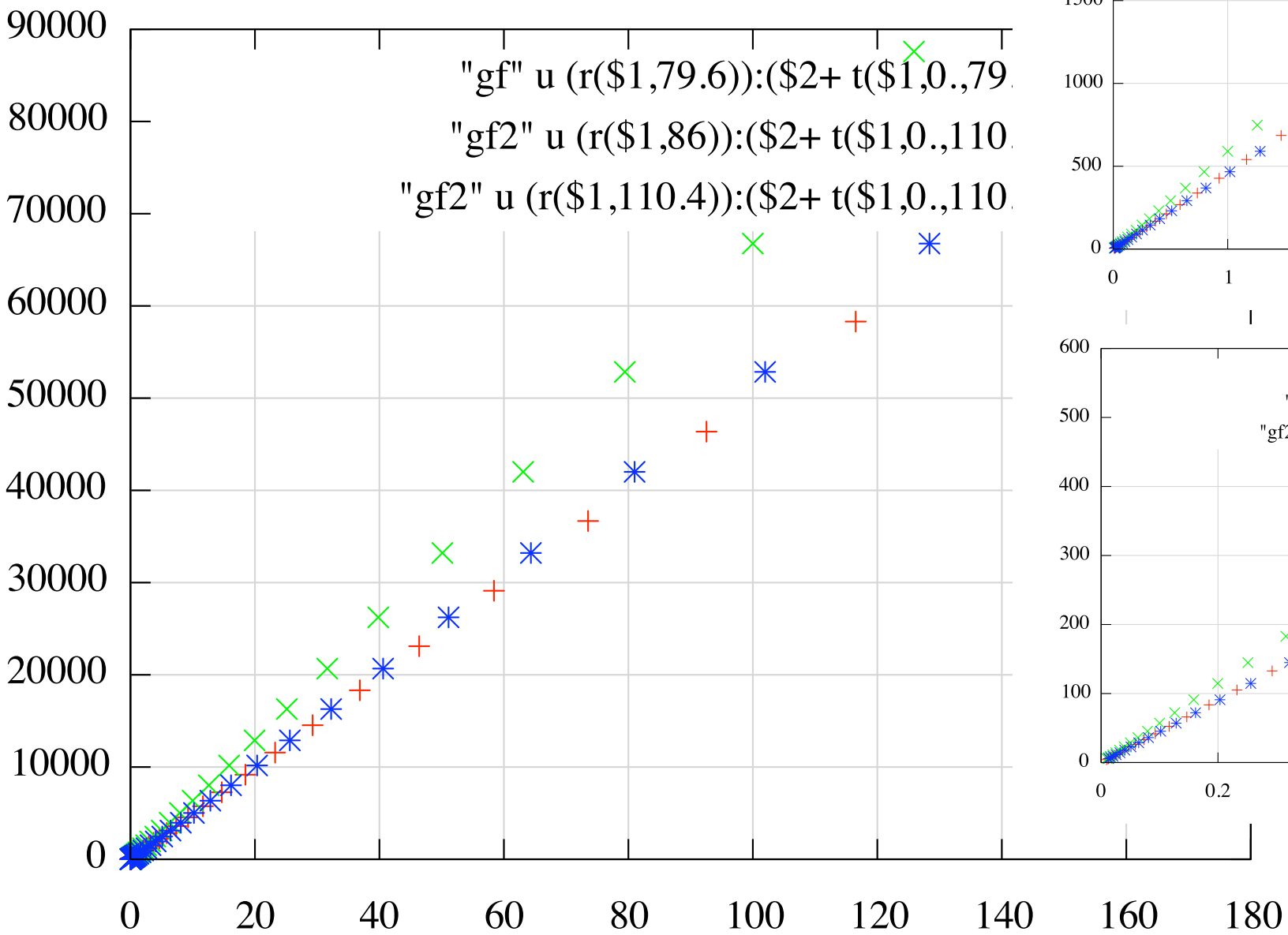
T90%

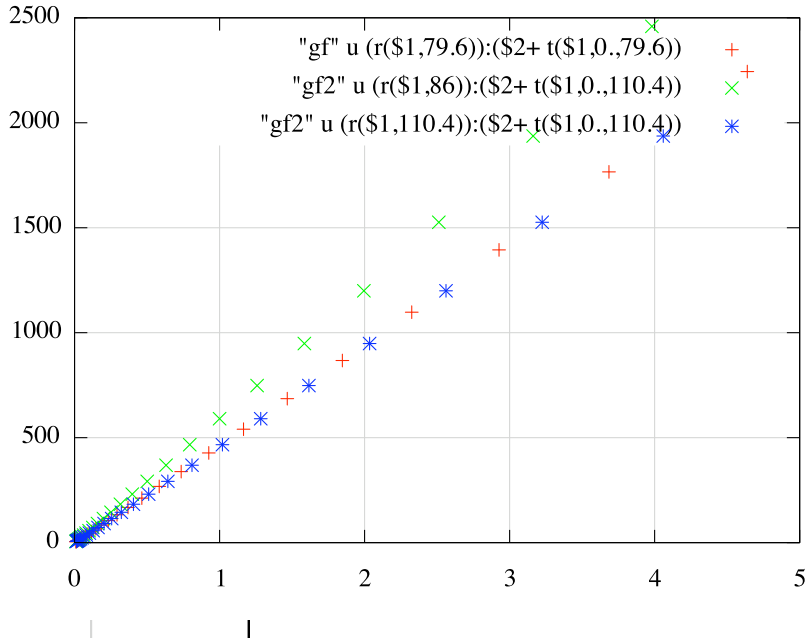


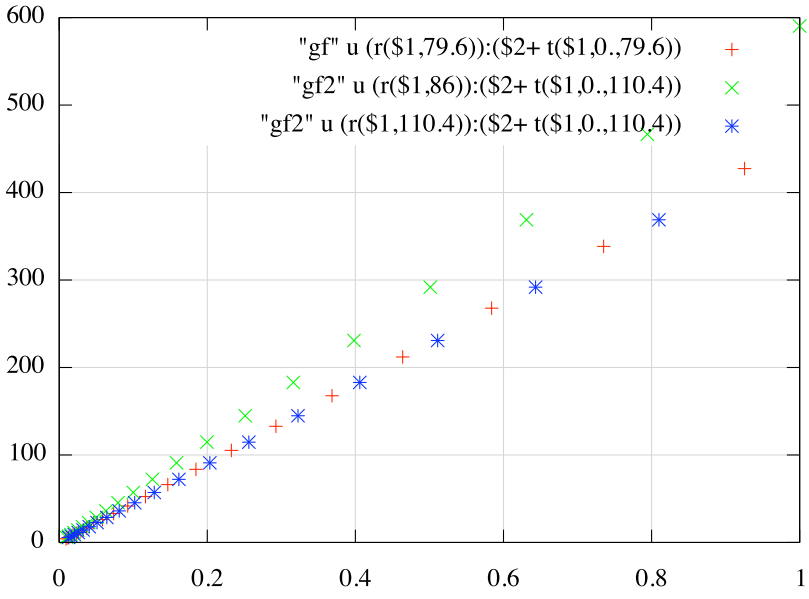
ibid

T50%

F7: gamma



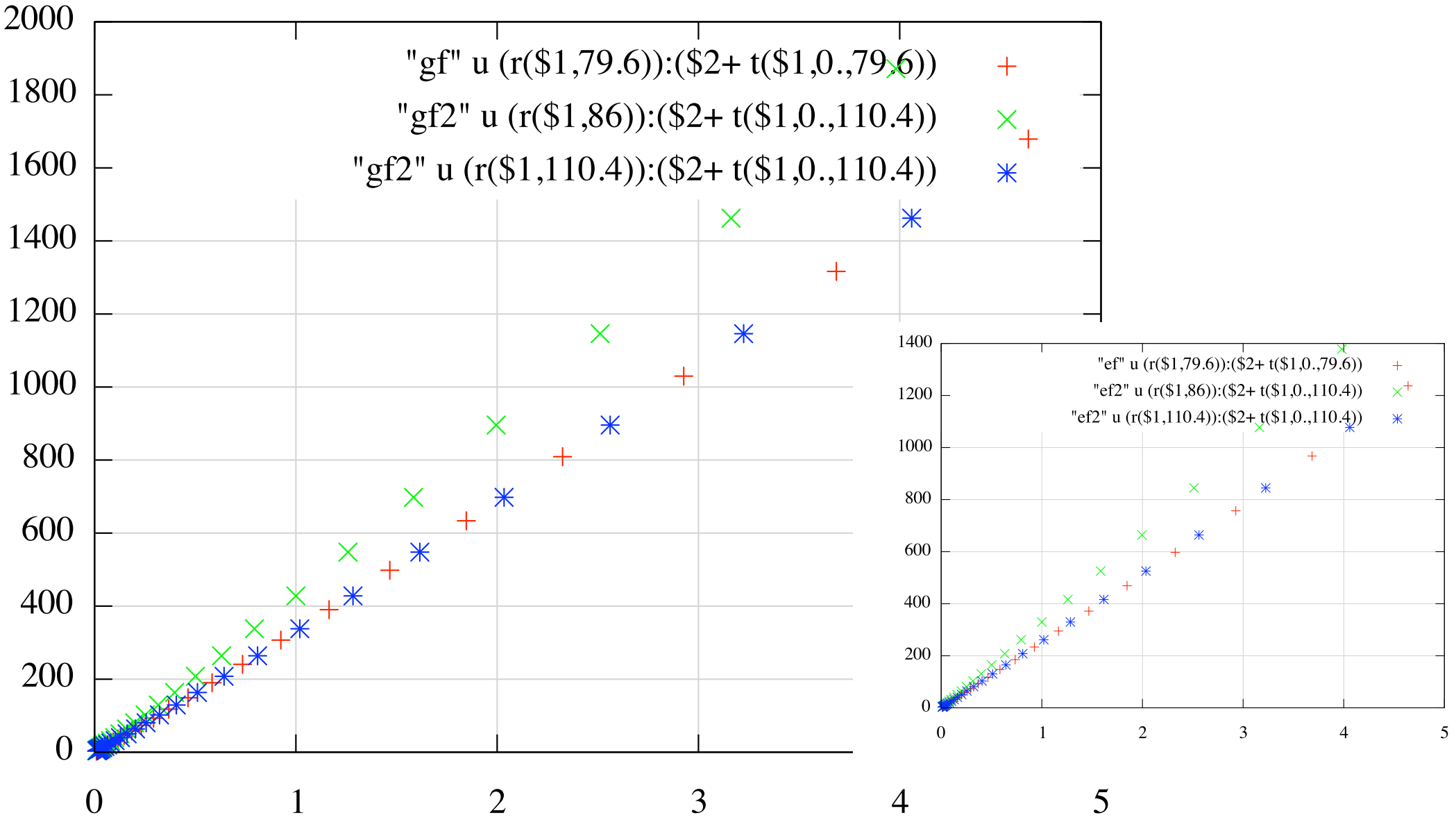




ibid

elec F3

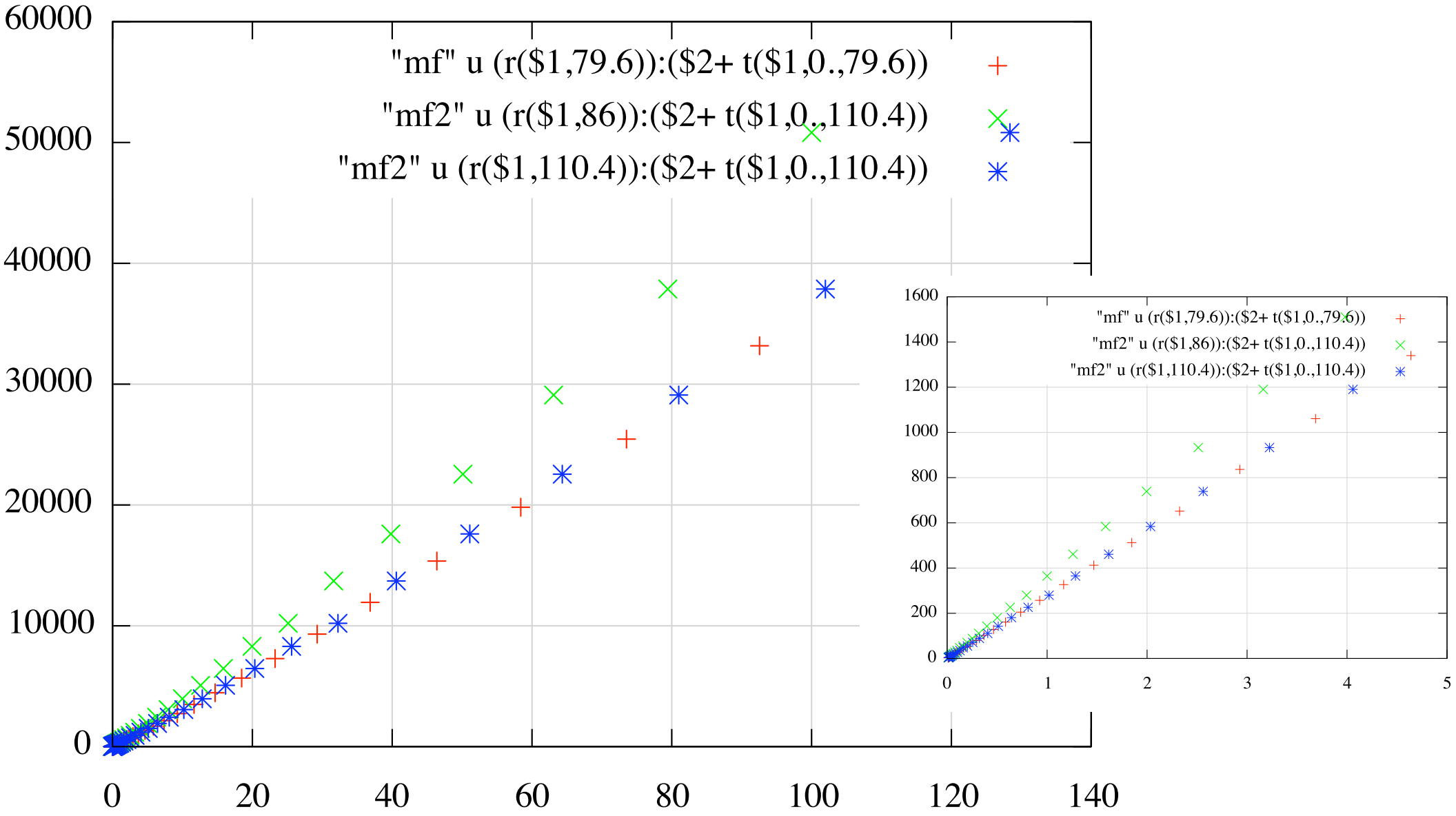
T50 %



ibid

F4: muon

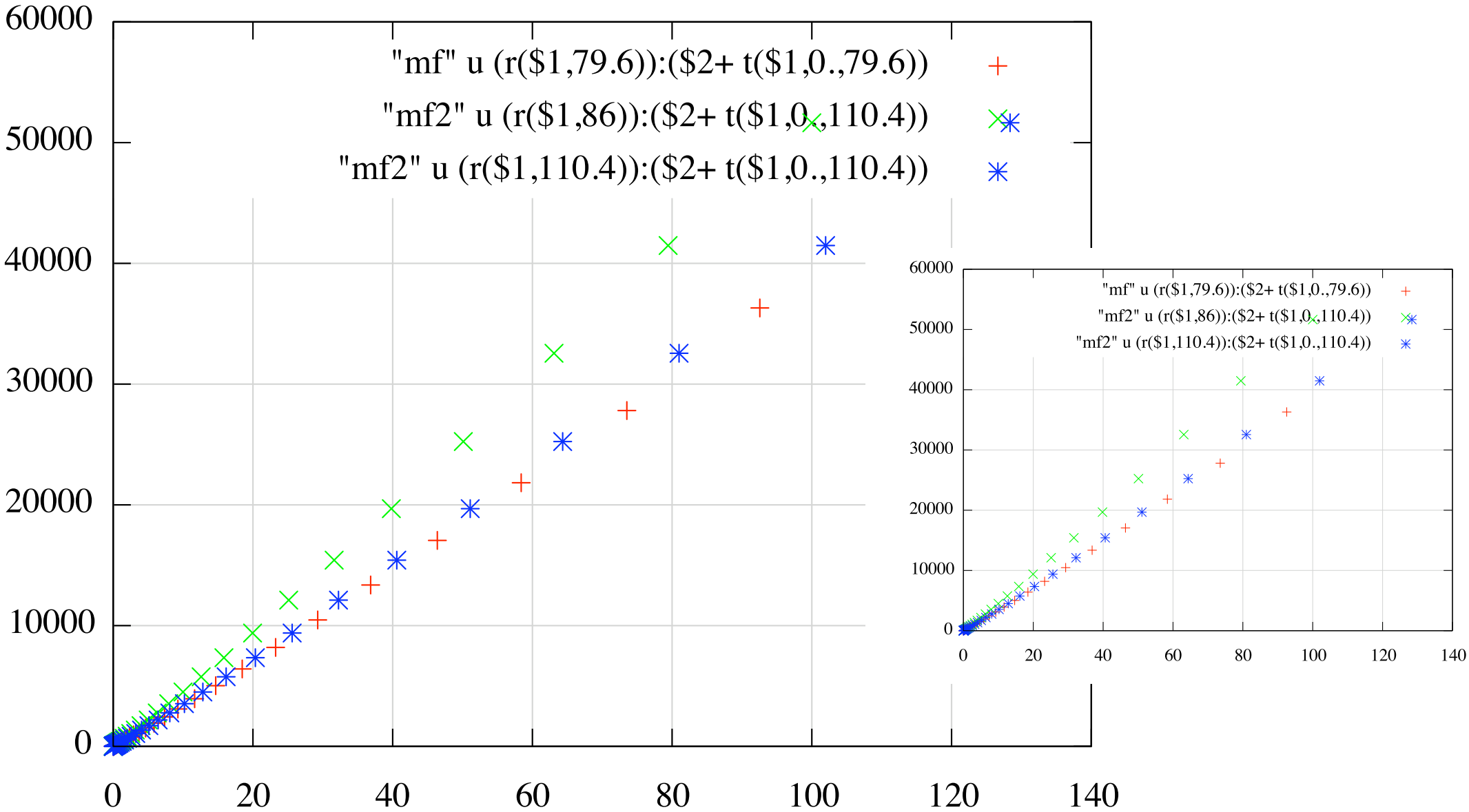
T10%

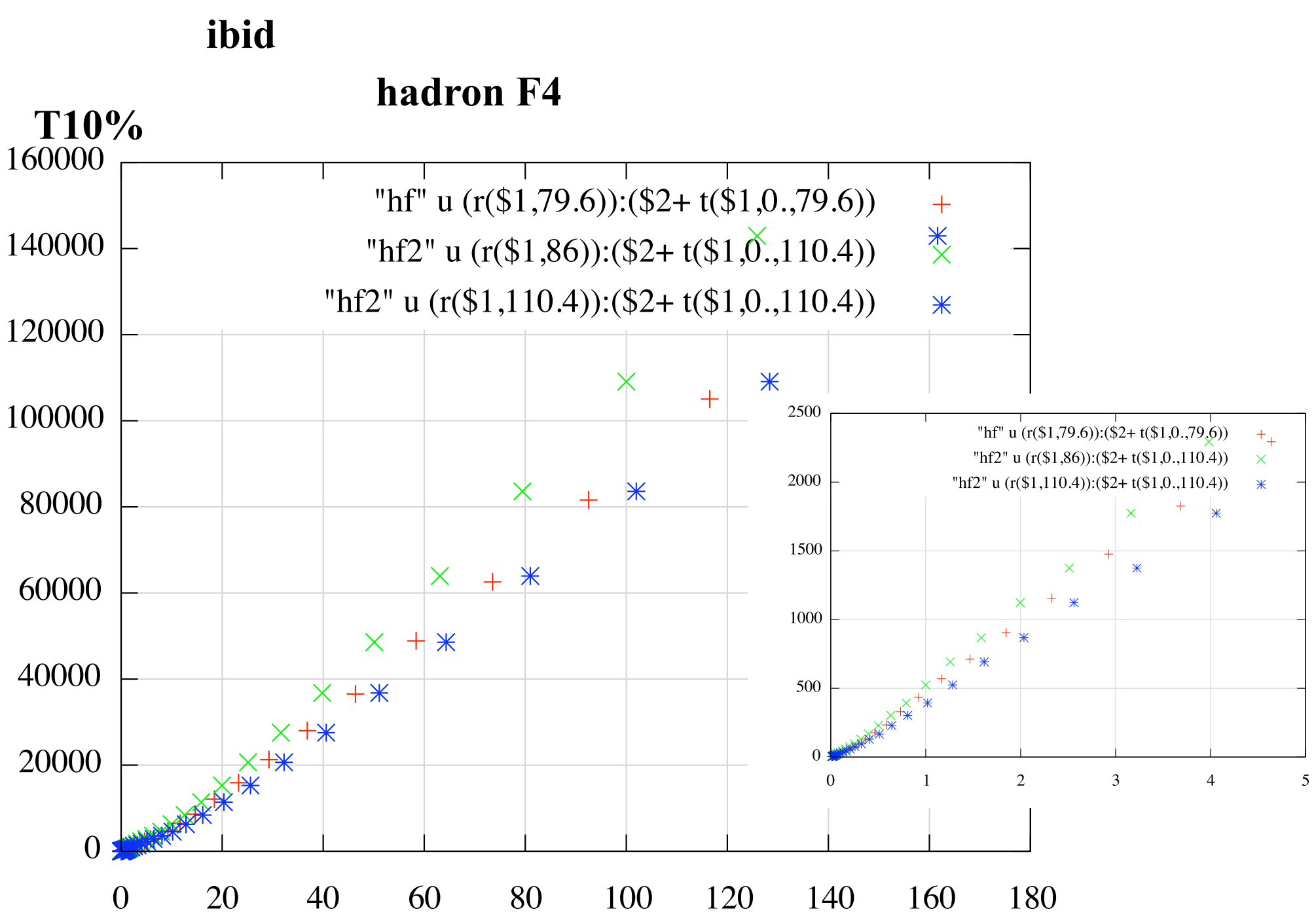


ibid

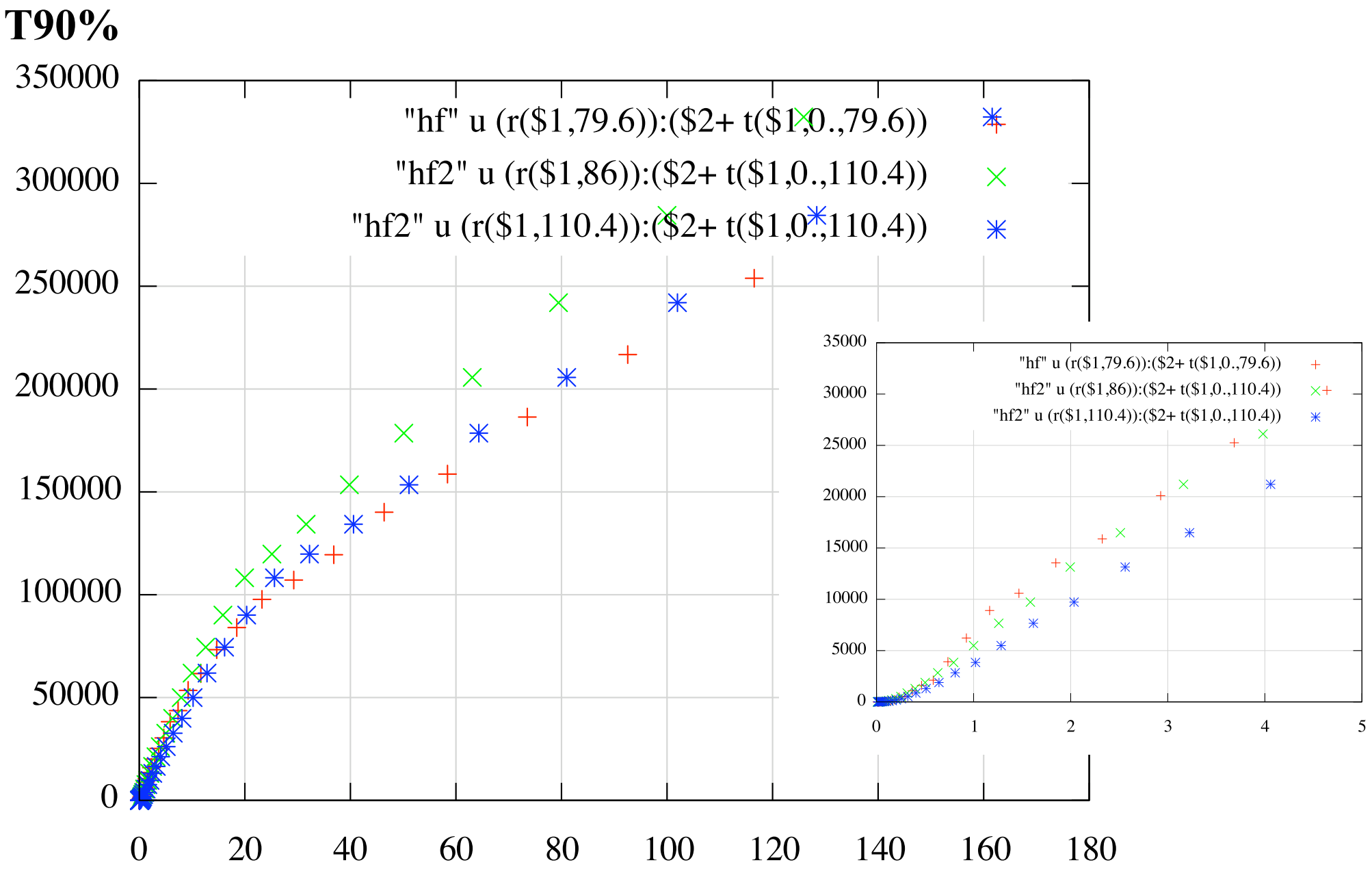
F4: muon

T50%




ibid
hadron F4
T10%
"hf" u (r($1,79.6)):($2+ t($1,0.,79.6))
"hf2" u (r($1,86)):($2+ t($1,0.,110.4))
"hf2" u (r($1,110.4)):($2+ t($1,0.,110.4))
160000
140000
120000
100000
80000
60000
40000
20000
0
0
20
40
60
80
100
120
140
160
180
2500
2000
1500
1000
500
0
0
1
2
3
4
5

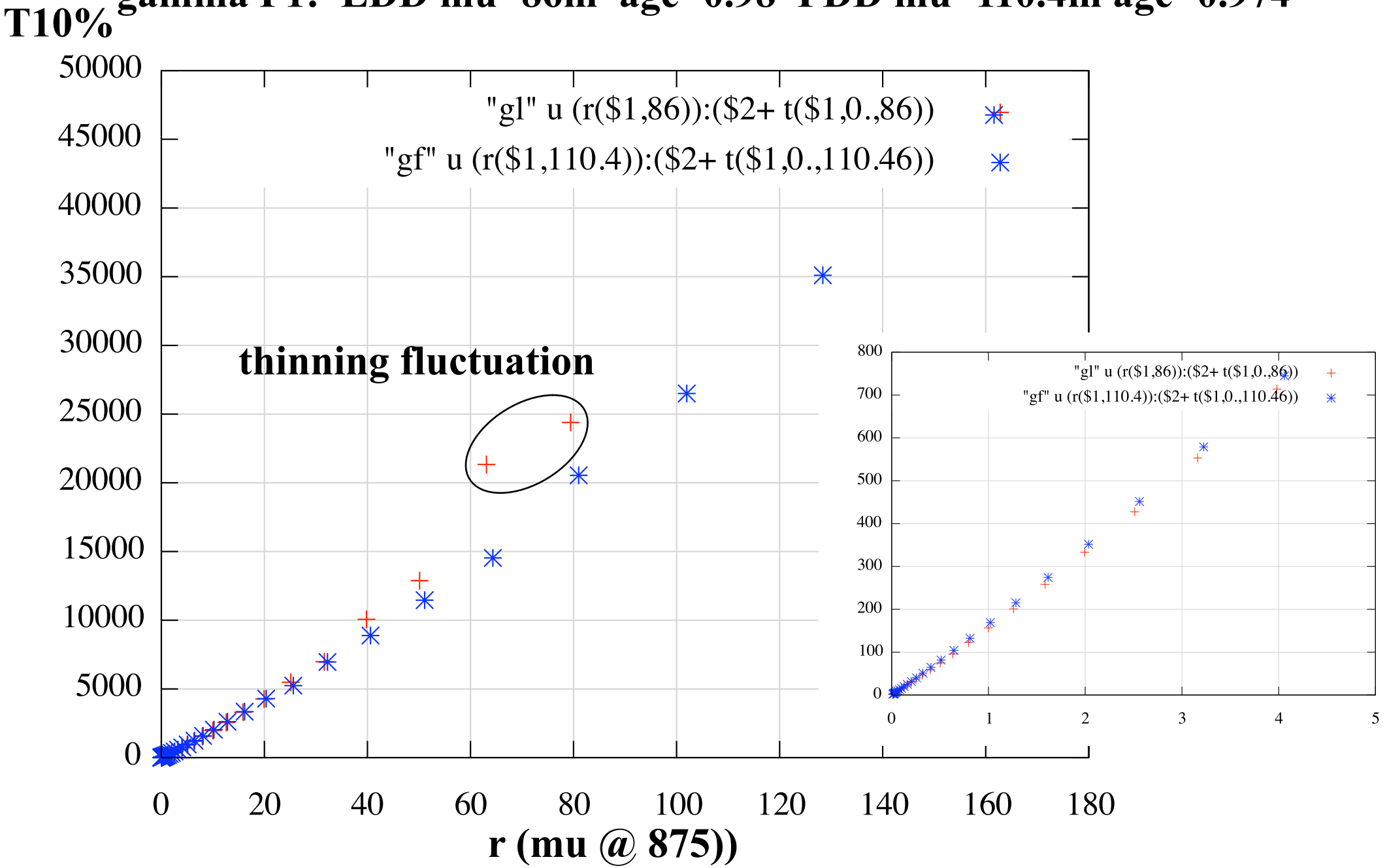
ibid hadron F4



LDD vs FDD

FDD is geometrically sclaed to LDD height.

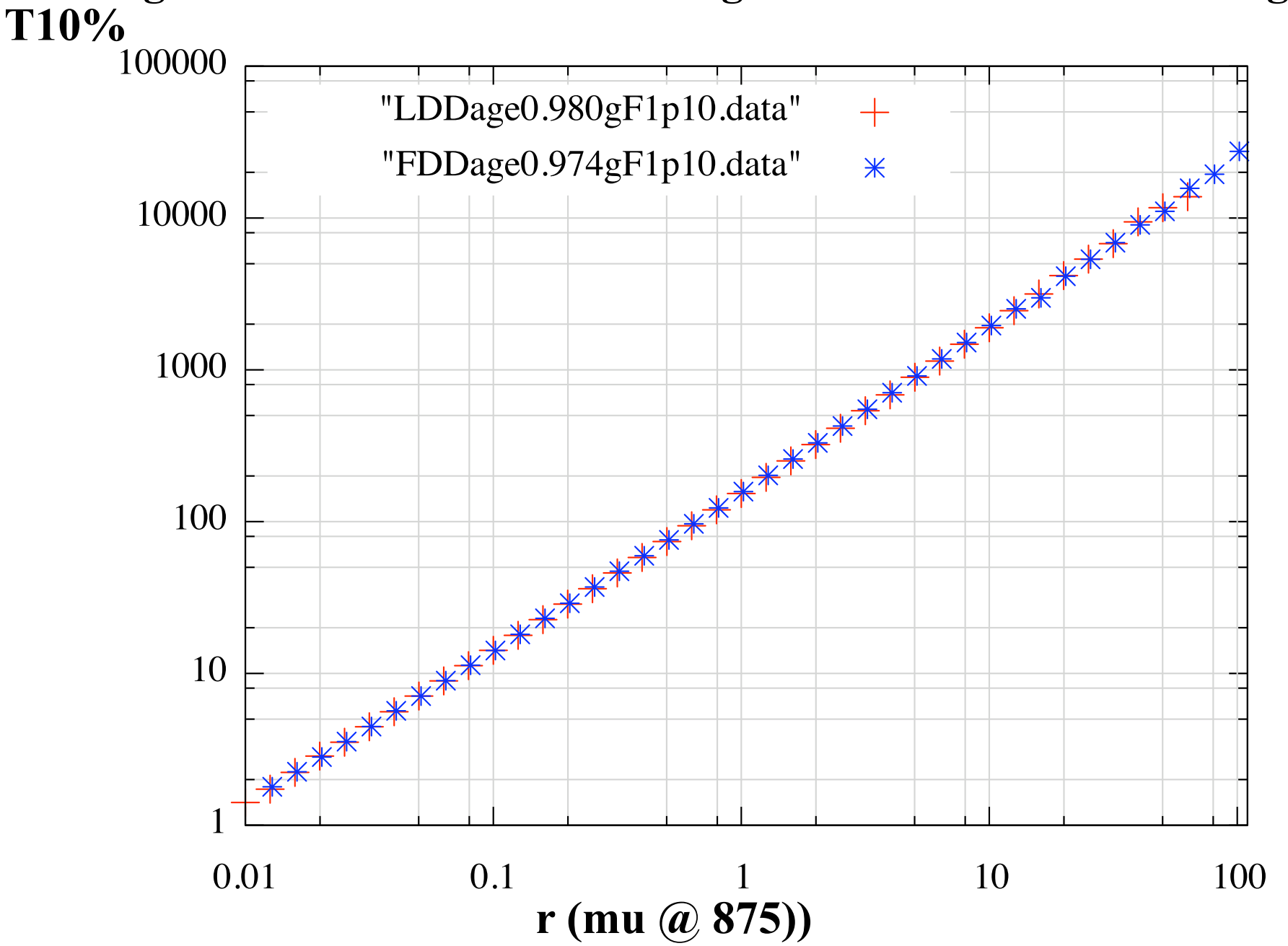
gamma F1: LDD mu=86m age=0.98 FDD mu=110.4m age=0.974



LDD vs FDD

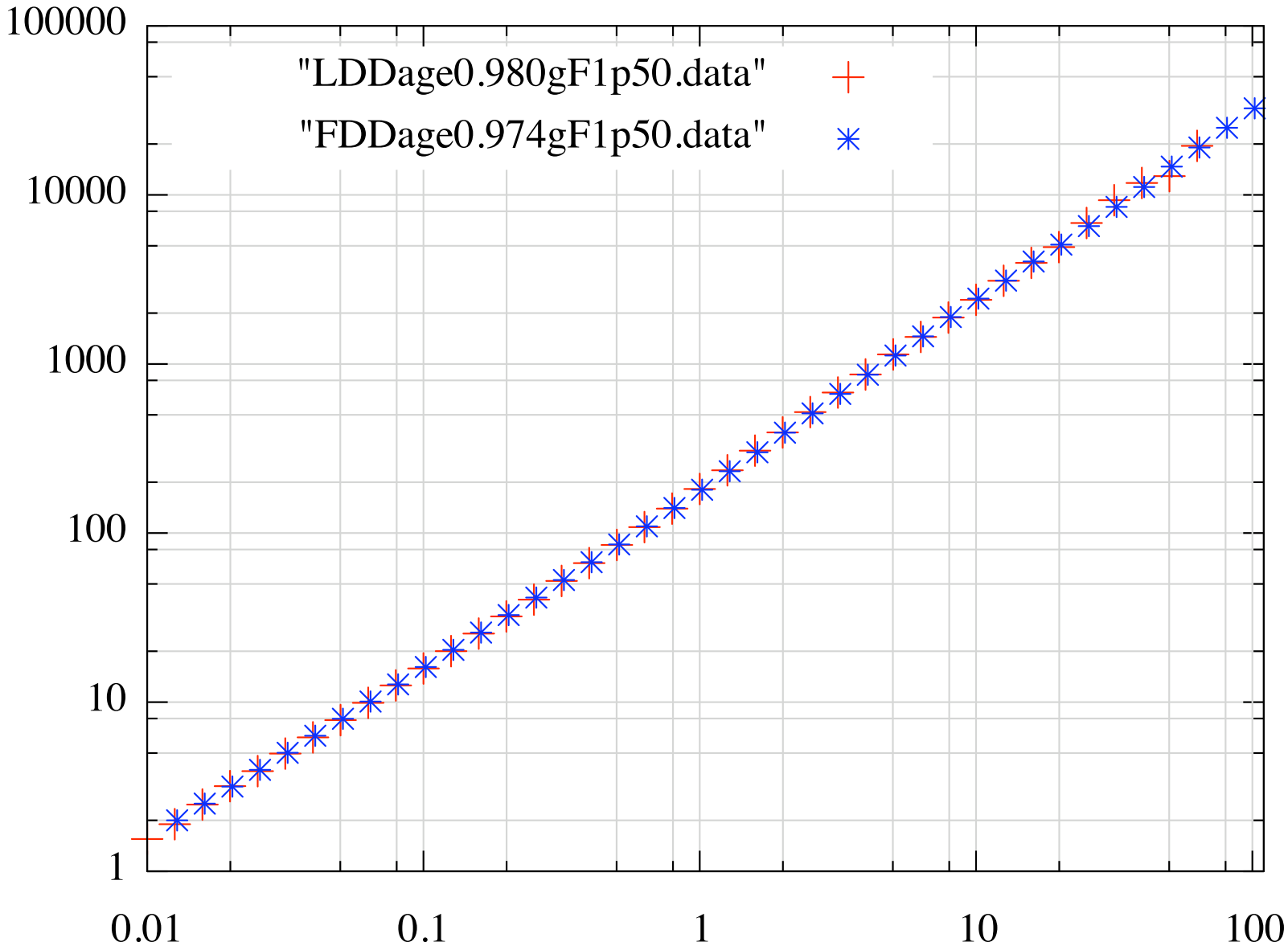
FDD is geometrically scaled to LDD height.

gamma F1: LDD mu=86m age=0.98 FDD mu=110.4m age=0.974



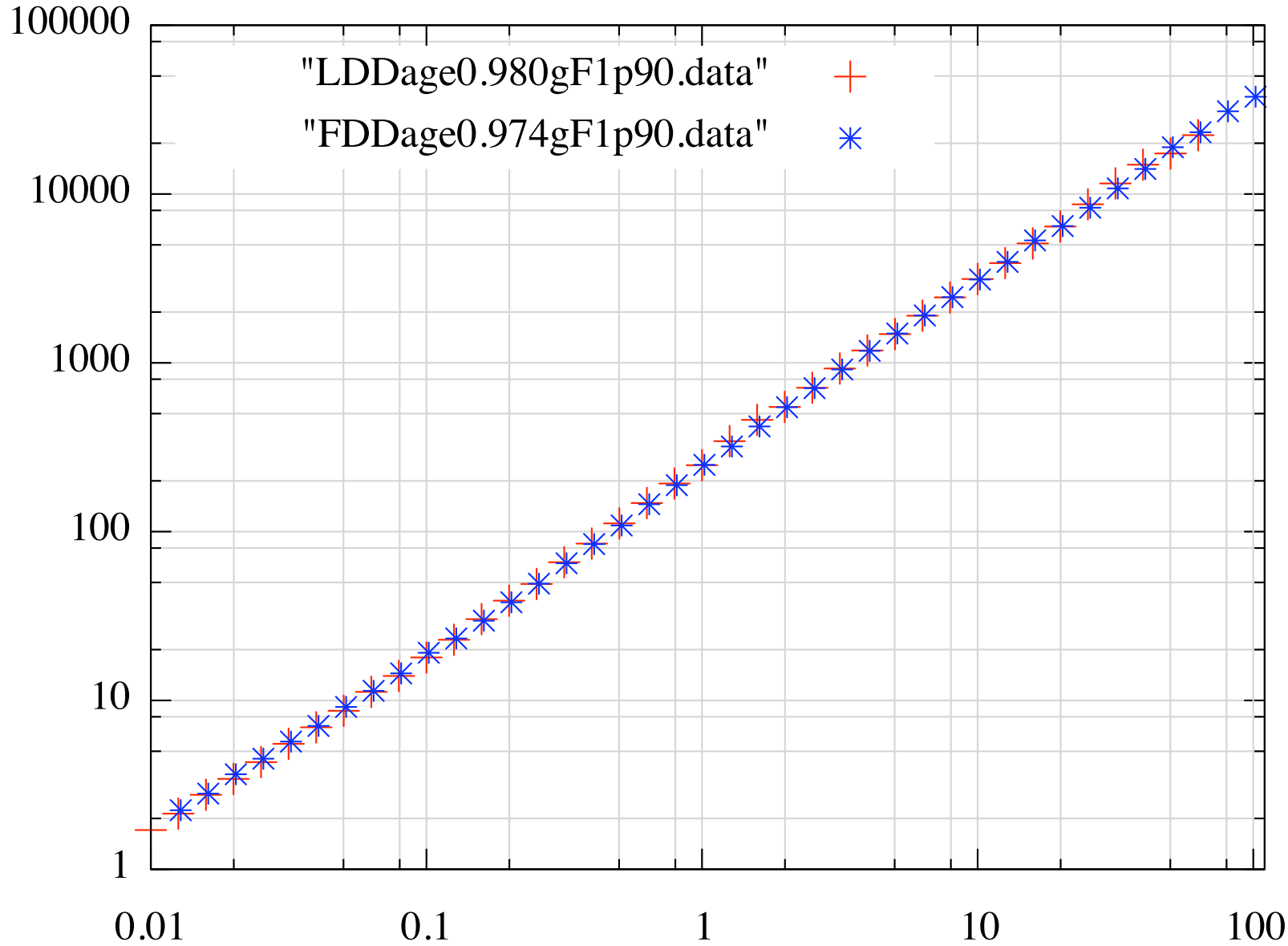
LDD vs FDD
ibid

T50% **gamma F1**

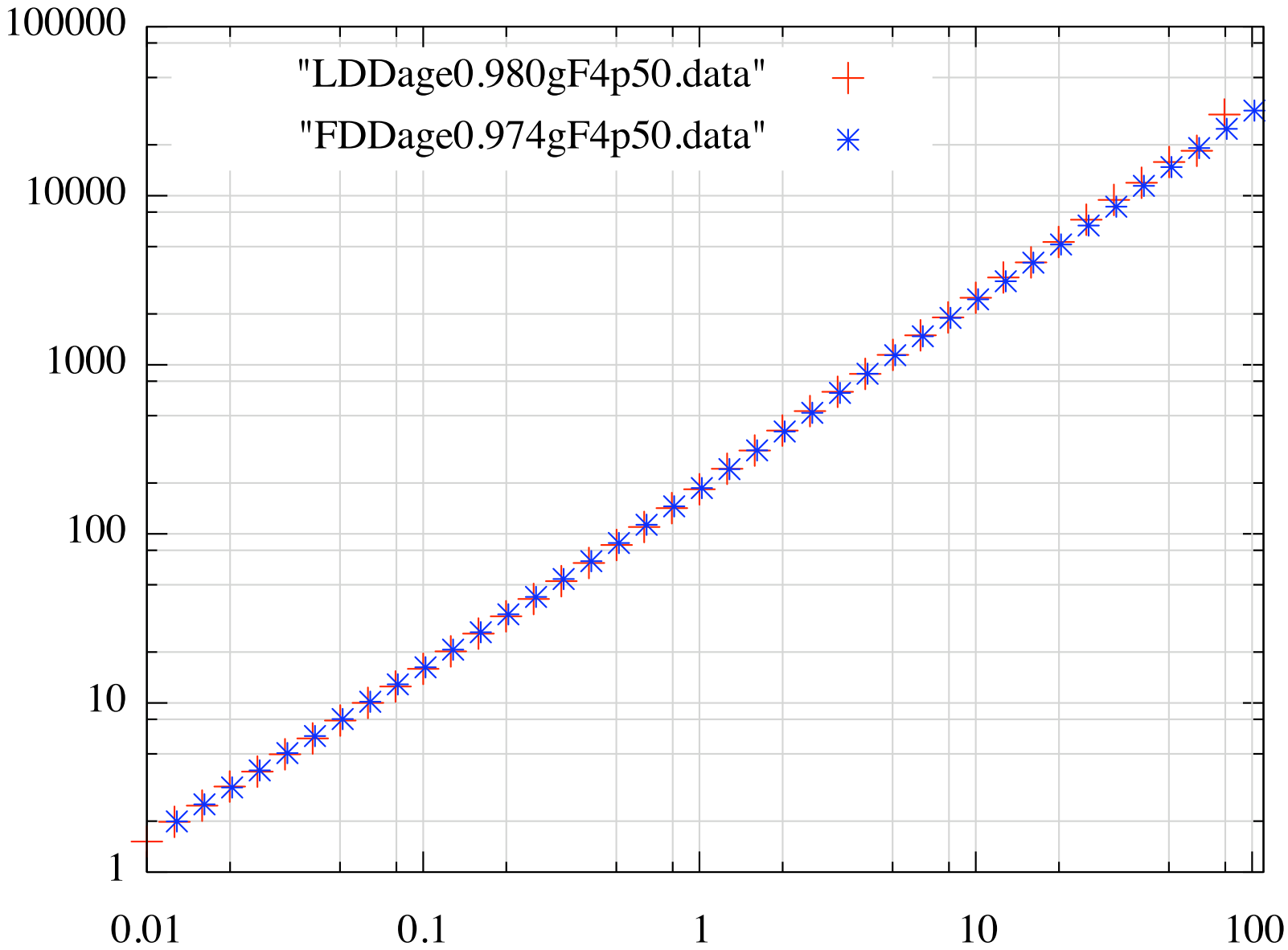


LDD vs FDD
ibid

T90% **gamma F1**



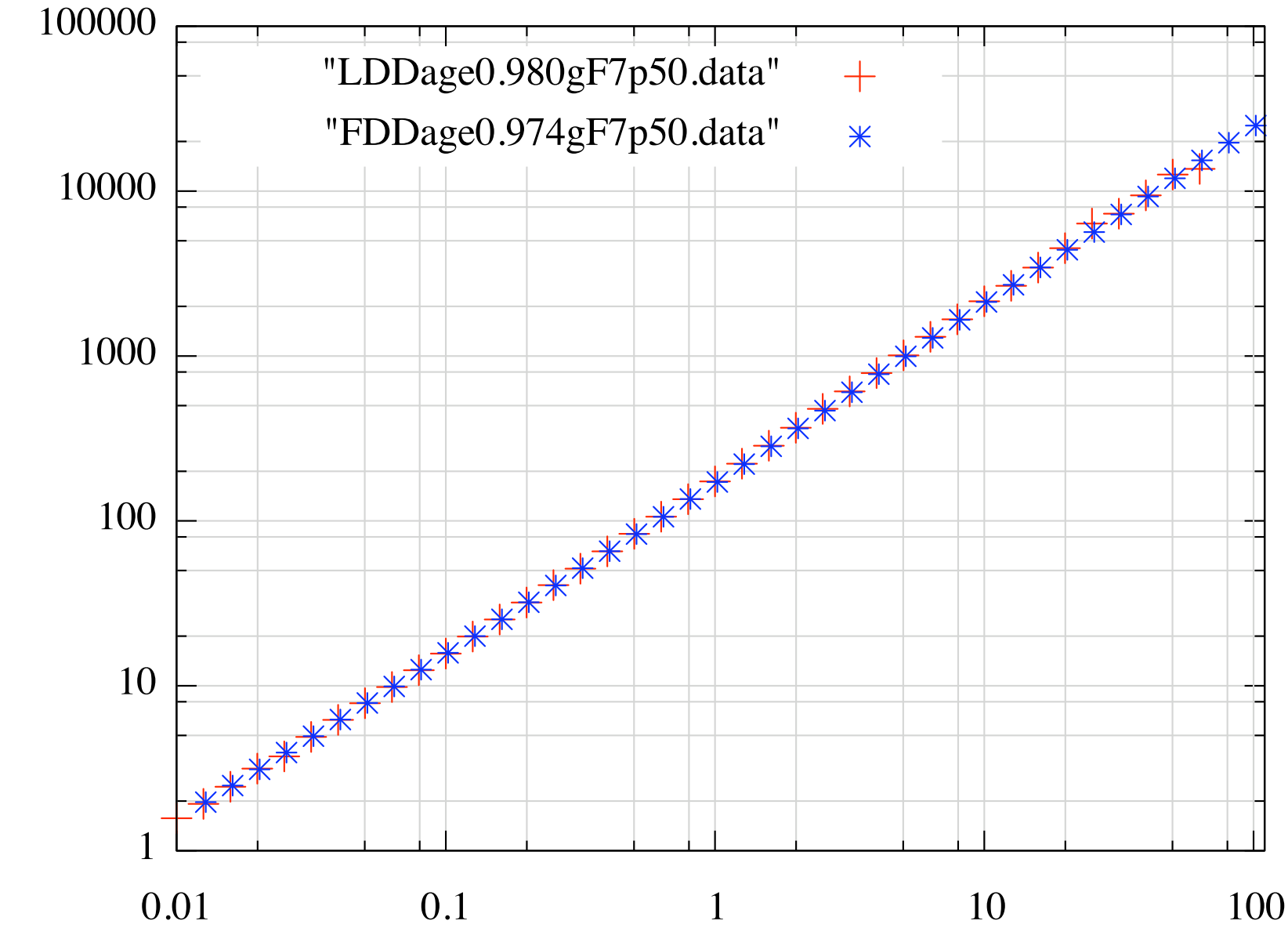
LDD vs FDD
ibid
gamma F4
T50%



LDD vs FDD
ibid

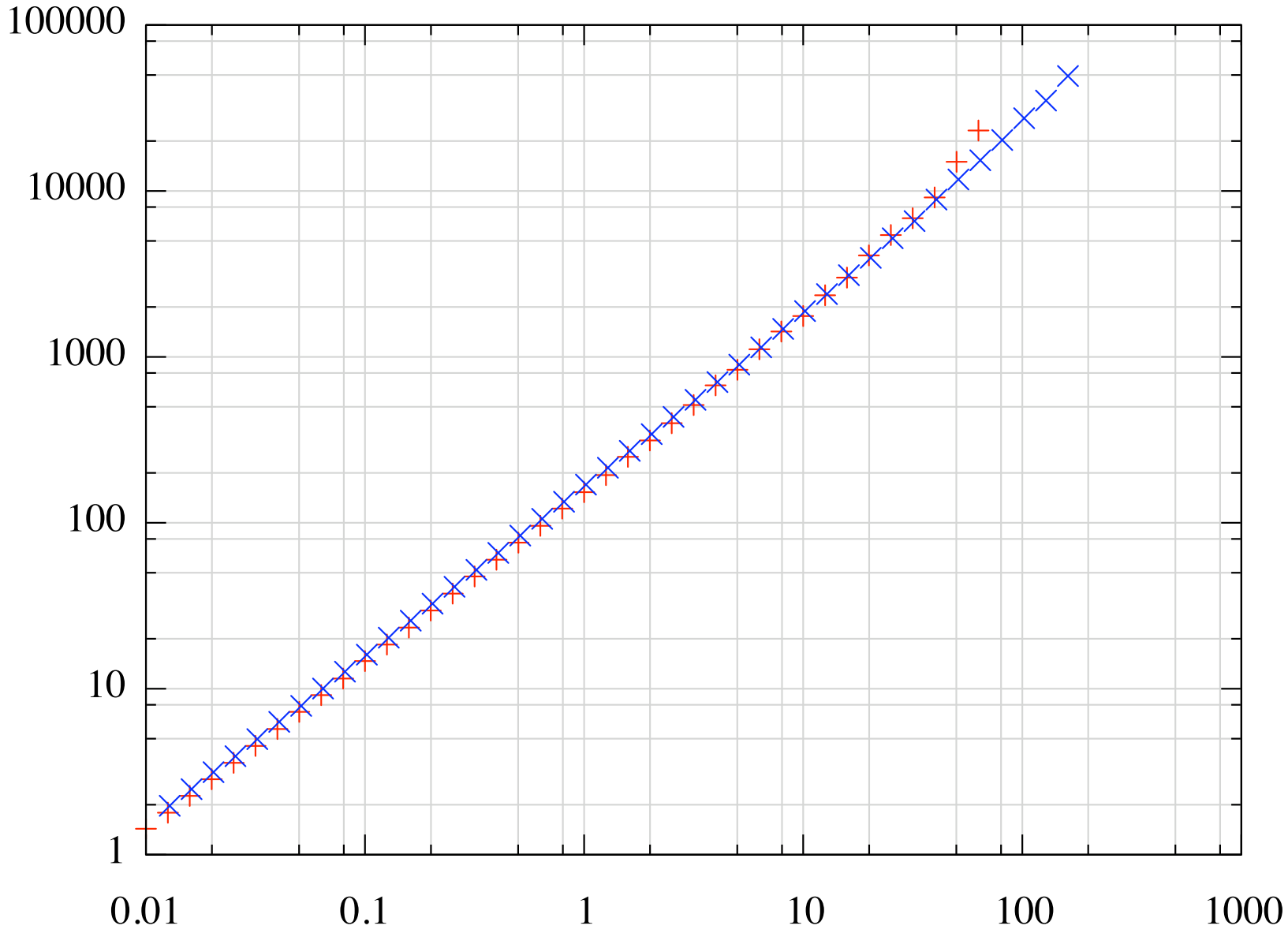
gamma F7

T50%



LDD vs FDD
ibid

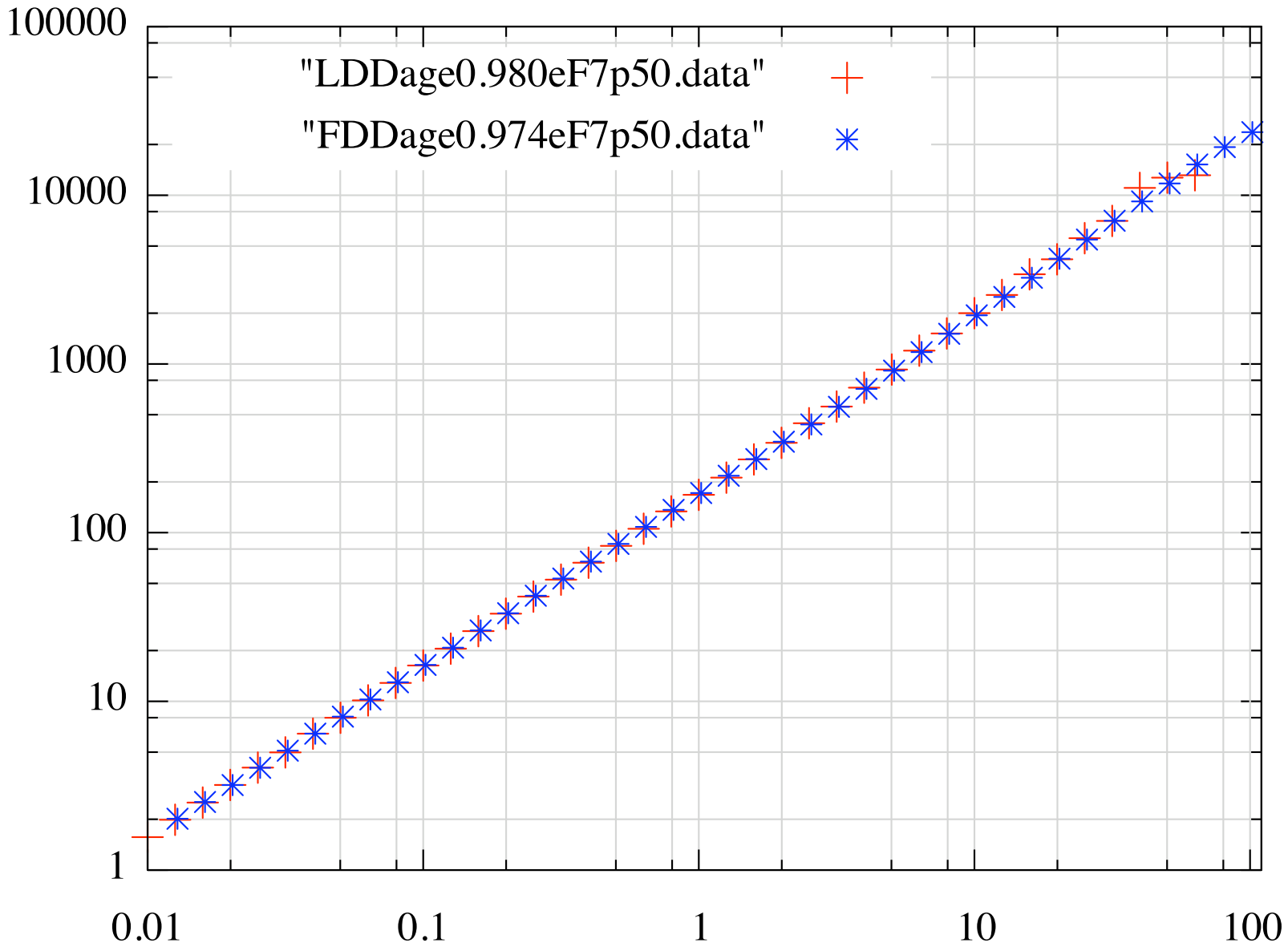
T10% **electron F1**



LDD vs FDD
ibid

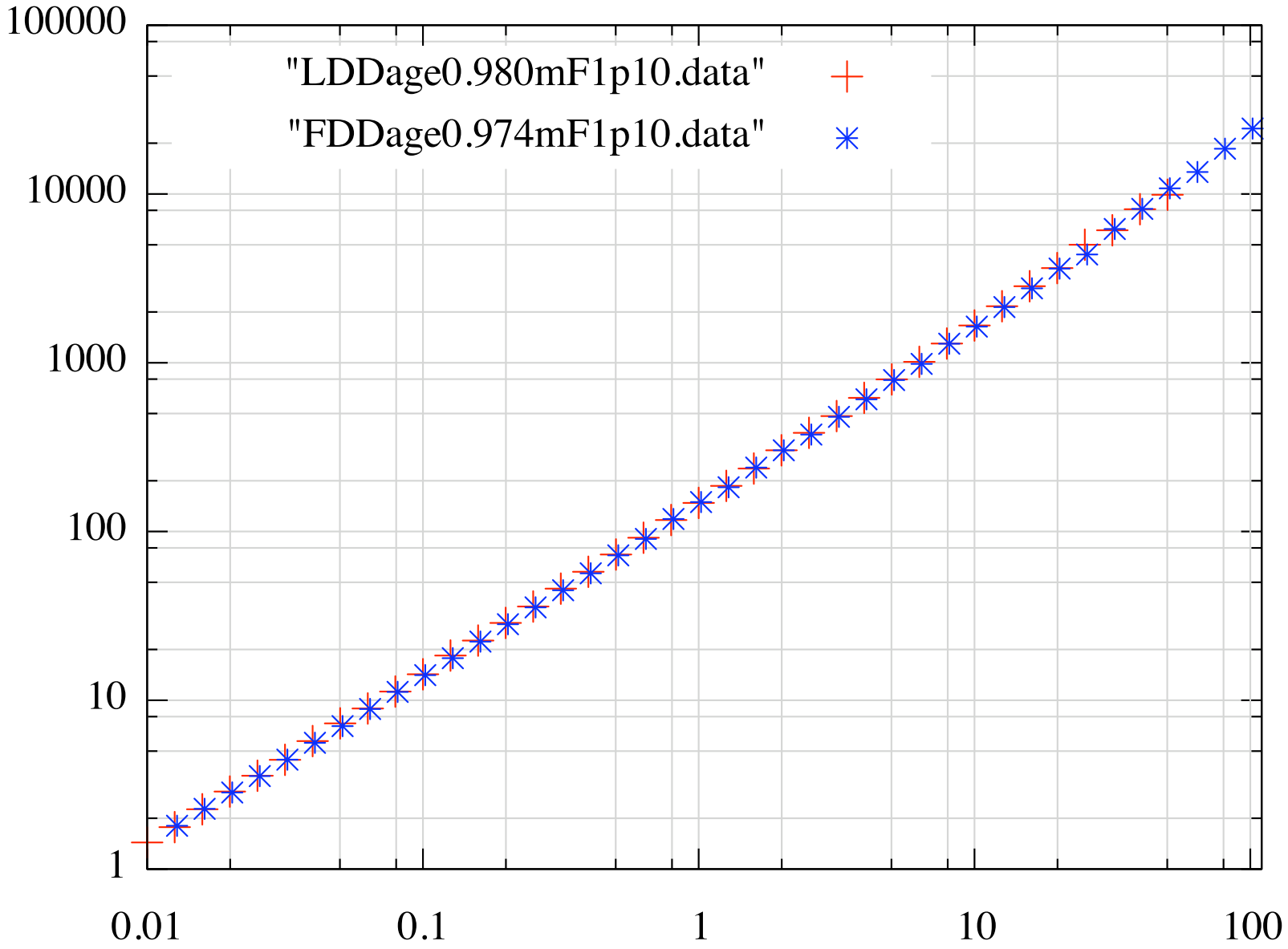
electron F7

T50%



LDD vs FDD
ibid

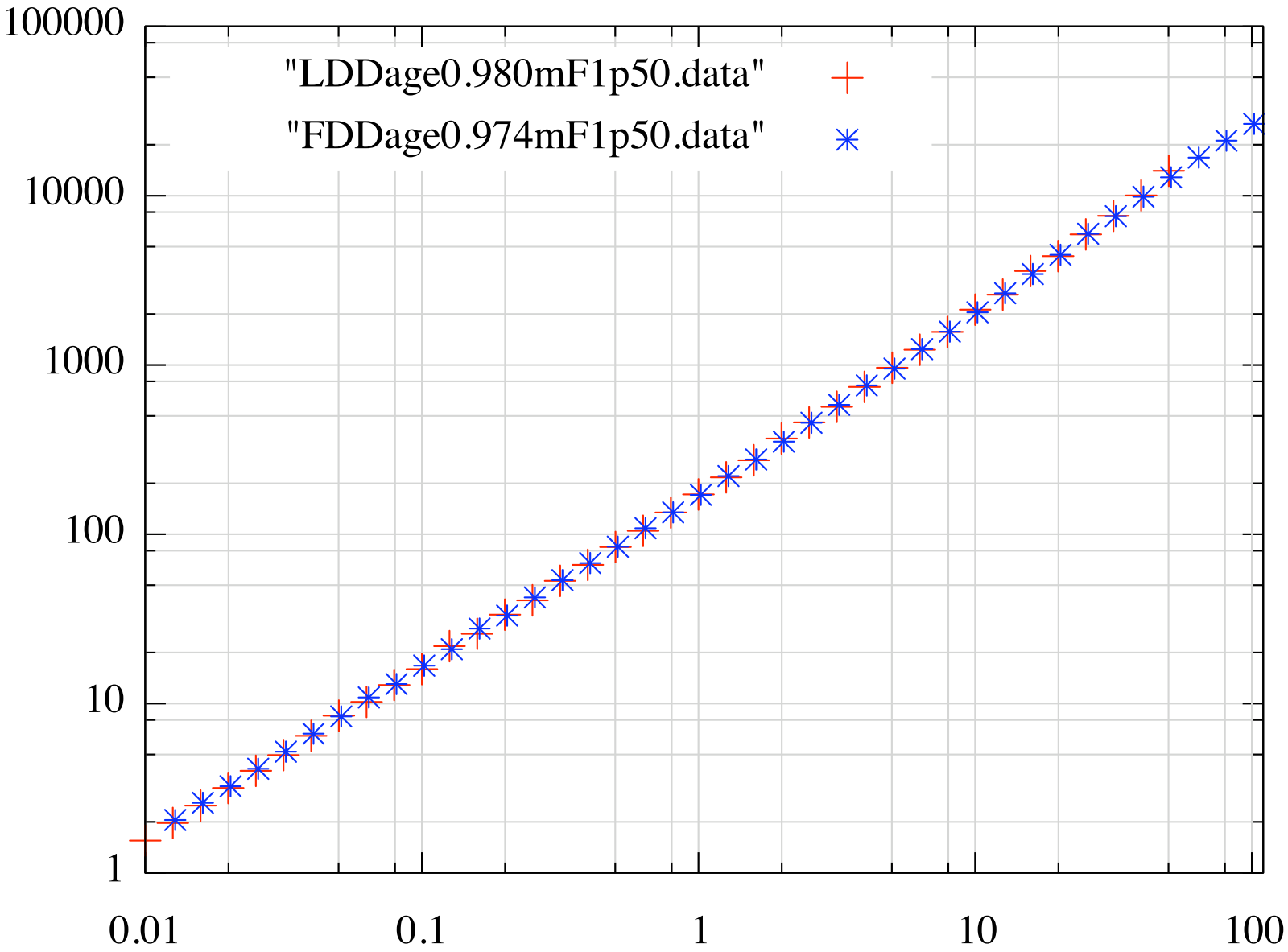
T10% **muon F1**



LDD vs FDD
ibid

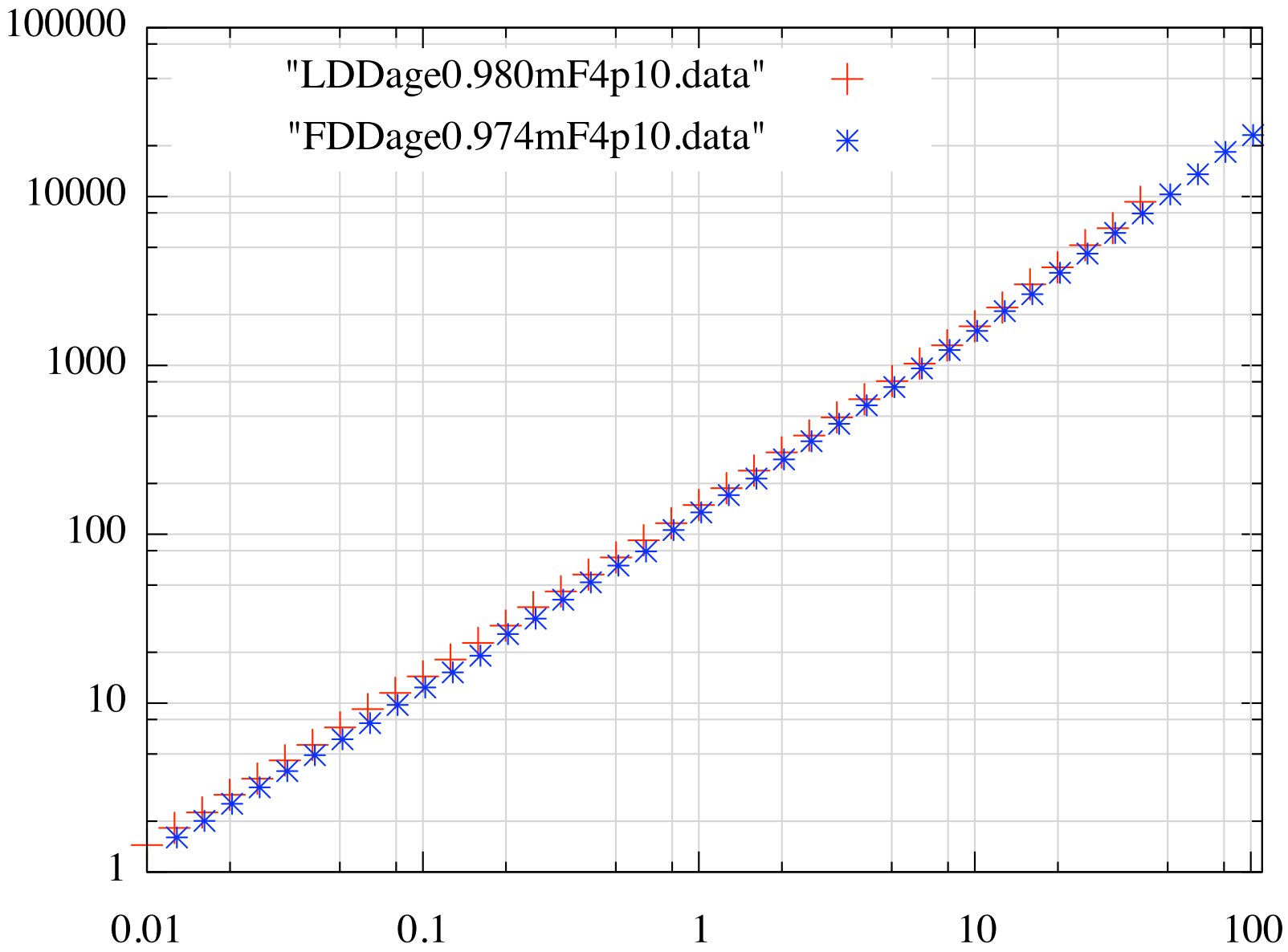
muon F1

T50%



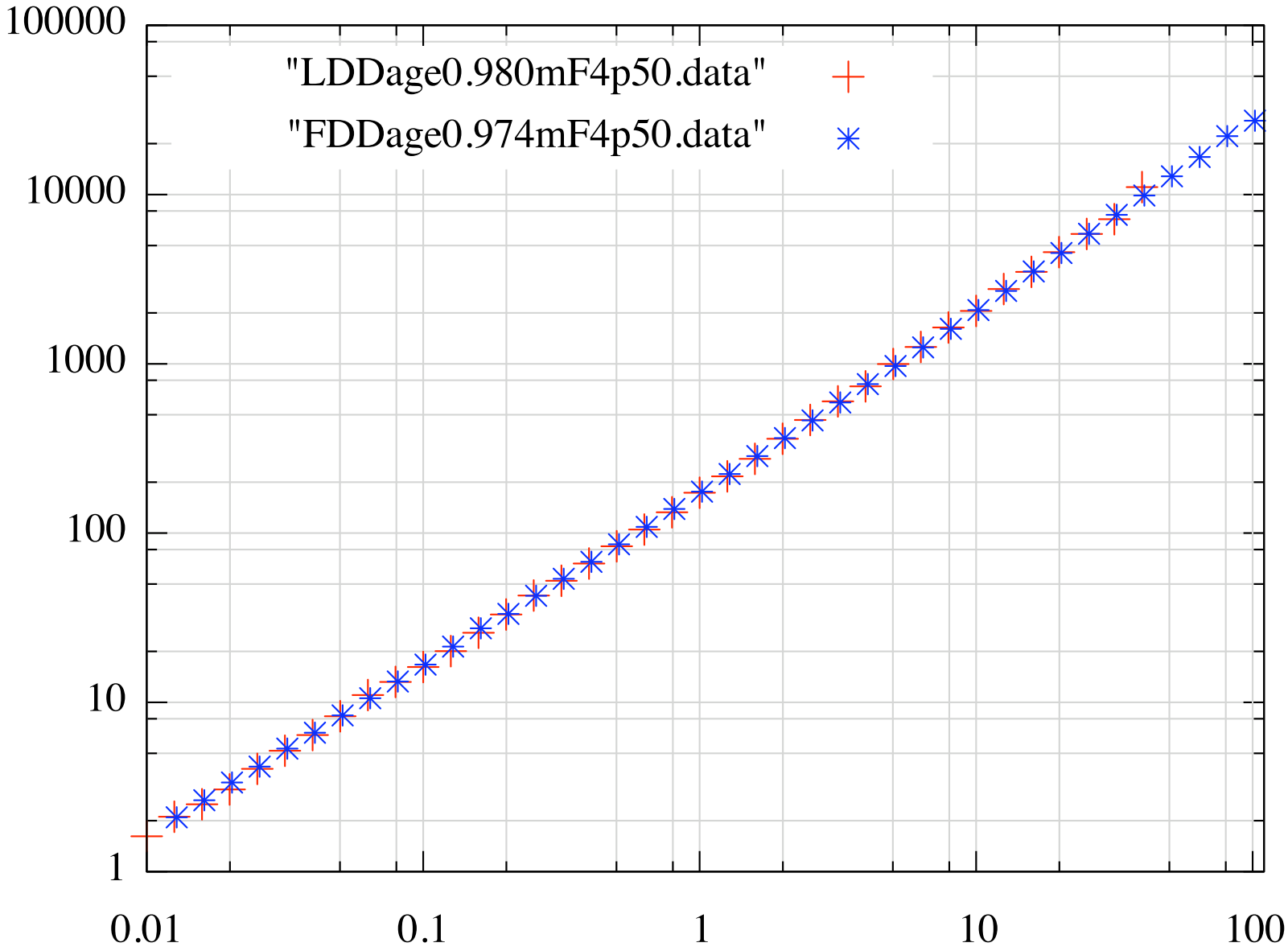
LDD vs FDD
ibid

T10% **muon F4**

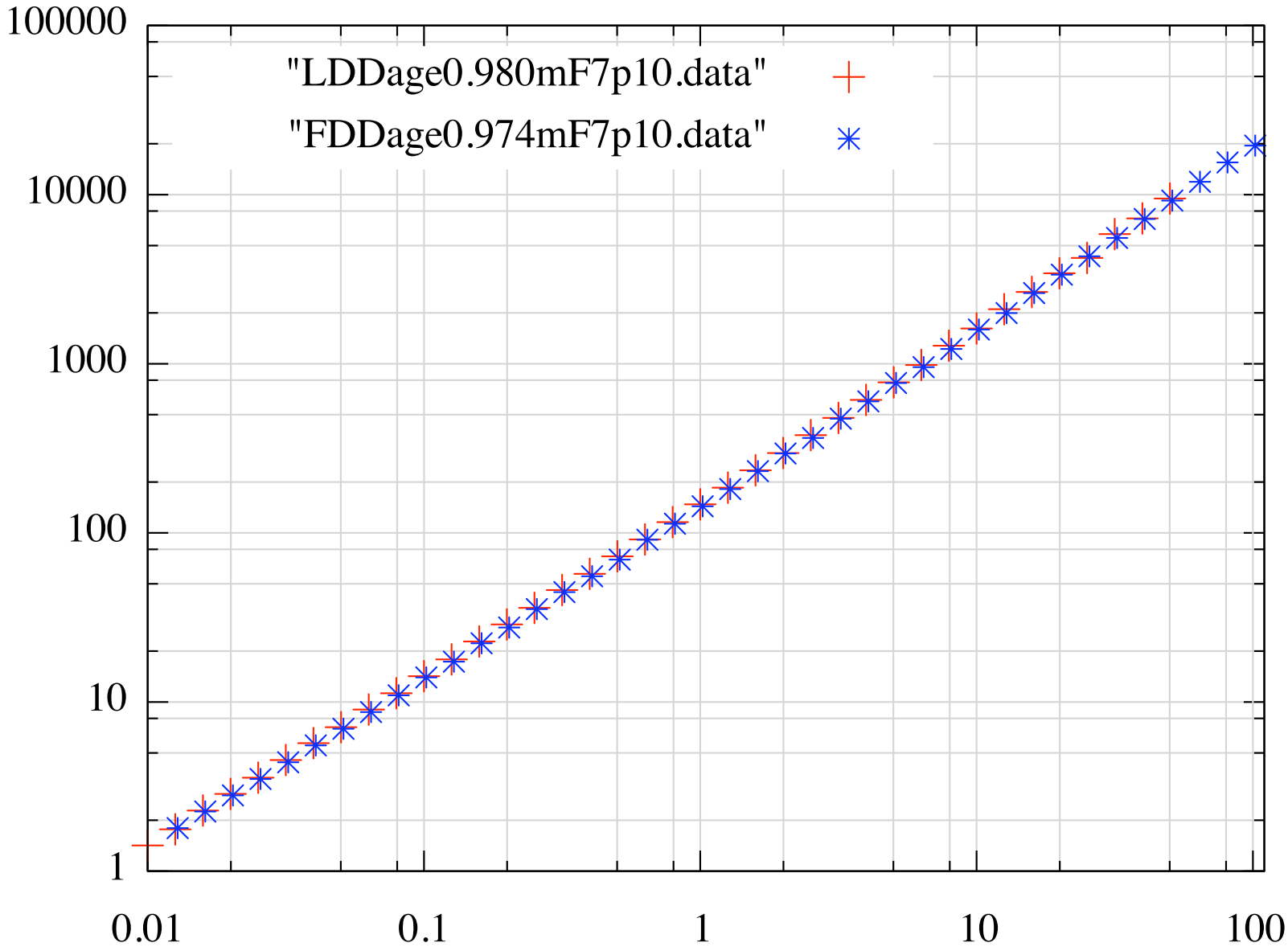


LDD vs FDD
ibid

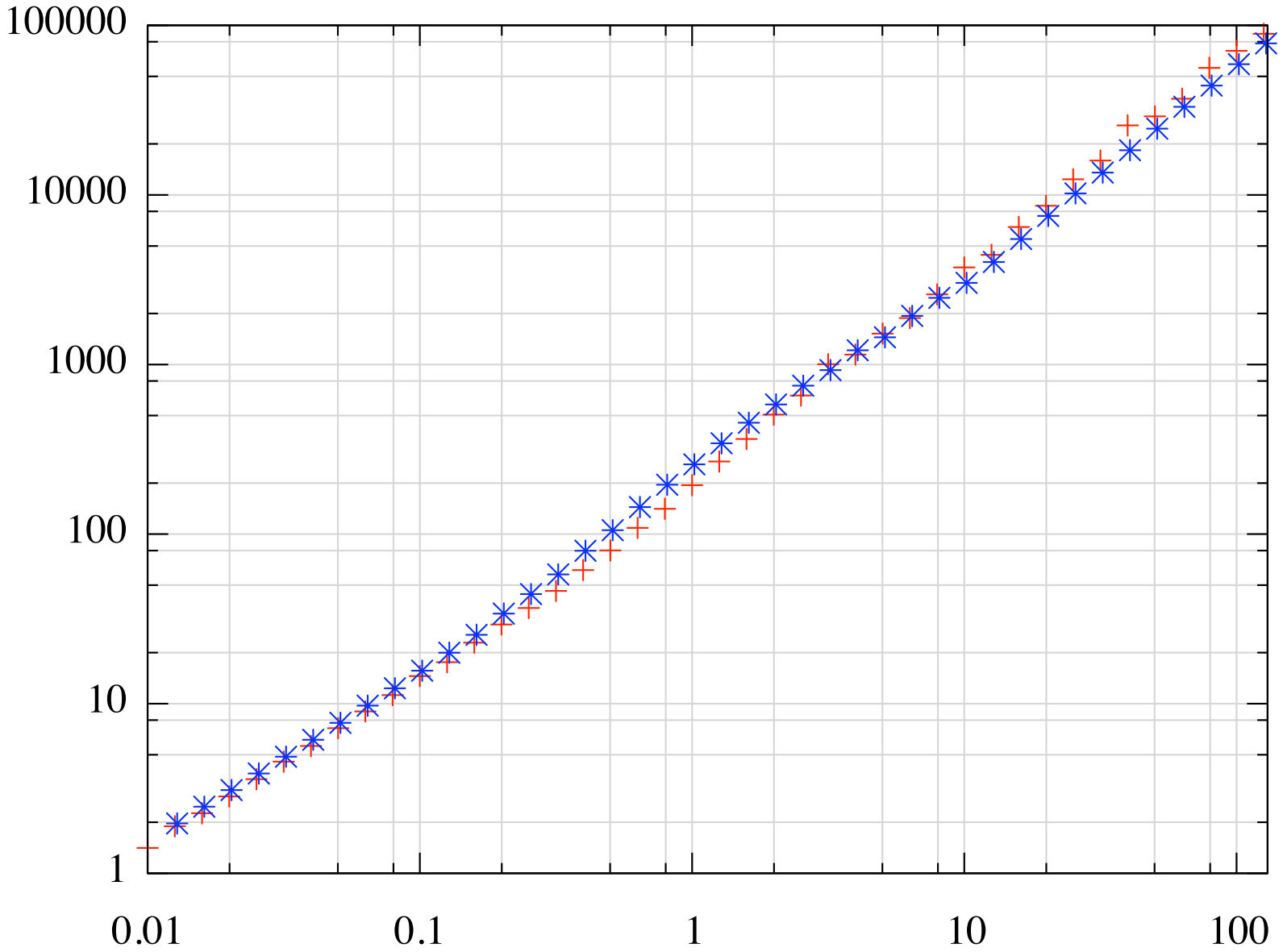
T50% **muon F4**



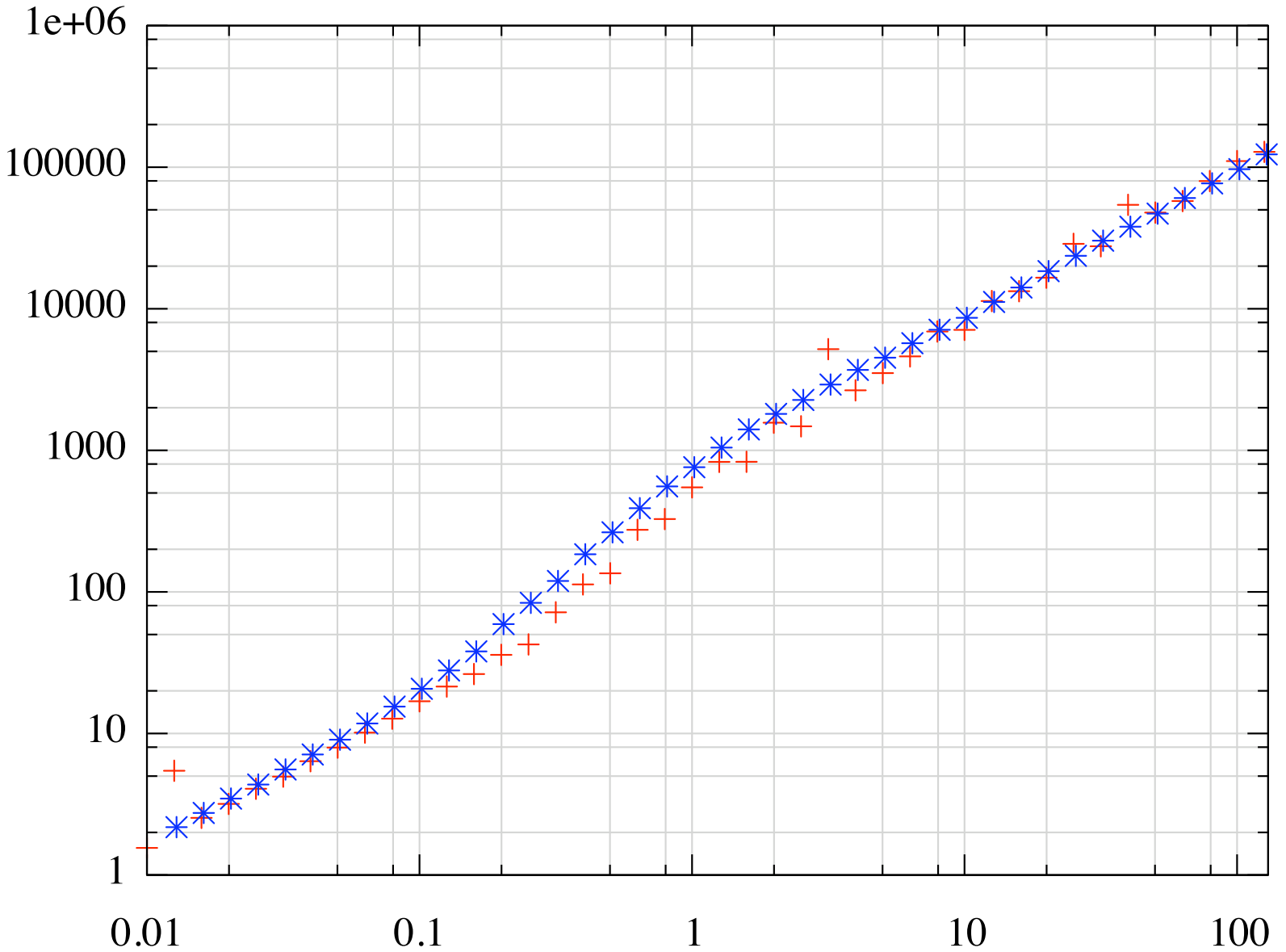
LDD vs FDD
ibid
T10% muon F7



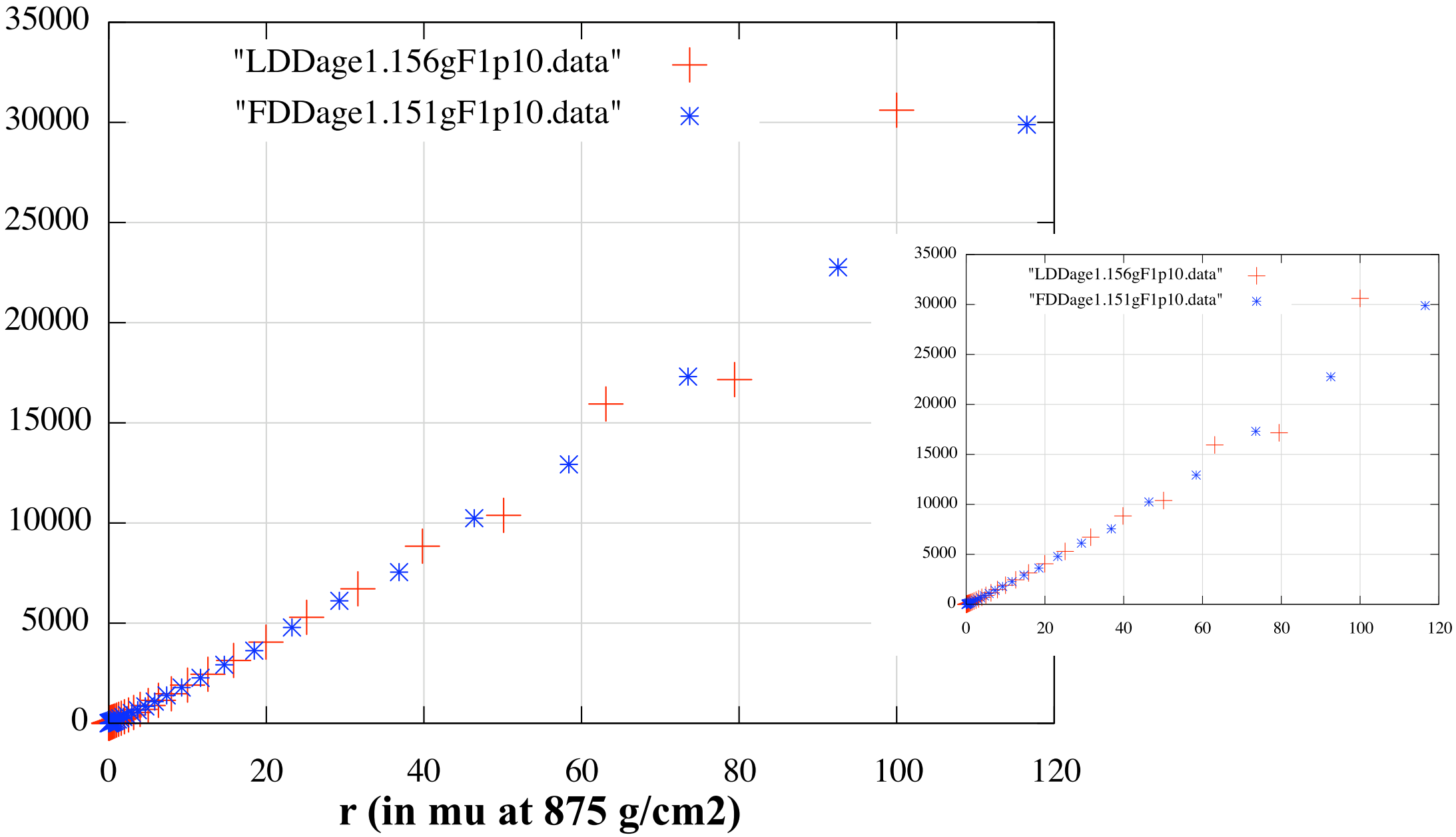
LDD vs FDD
ibid
T10% hadron F1



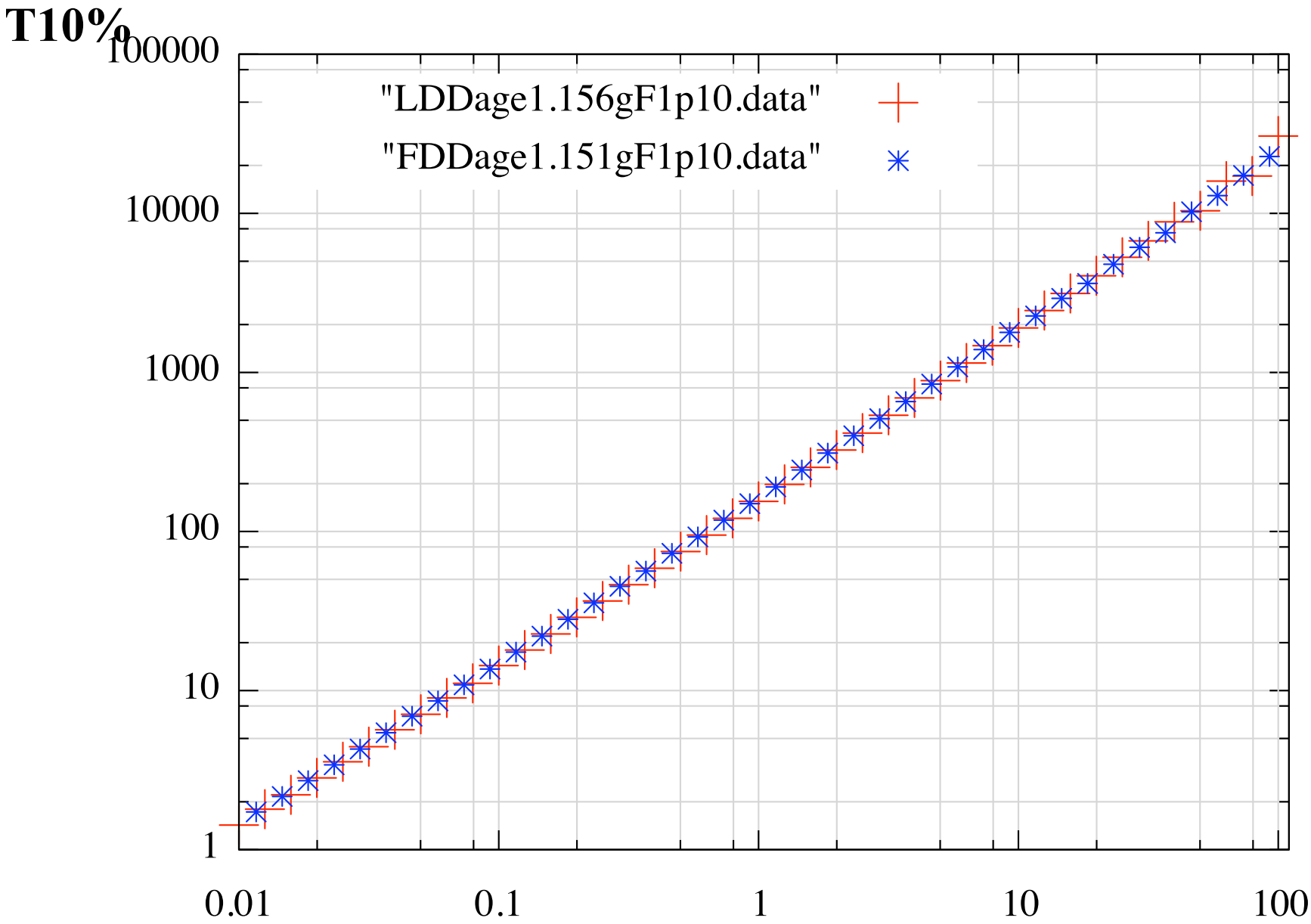
LDD vs FDD
ibid
T50% hadron F1



LDD vs FDD 2
FDD is geometrically sclaed to LDD height.
gamma F1: LDD mu=86m age=1.156 FDD mu=79.6 age=1.151

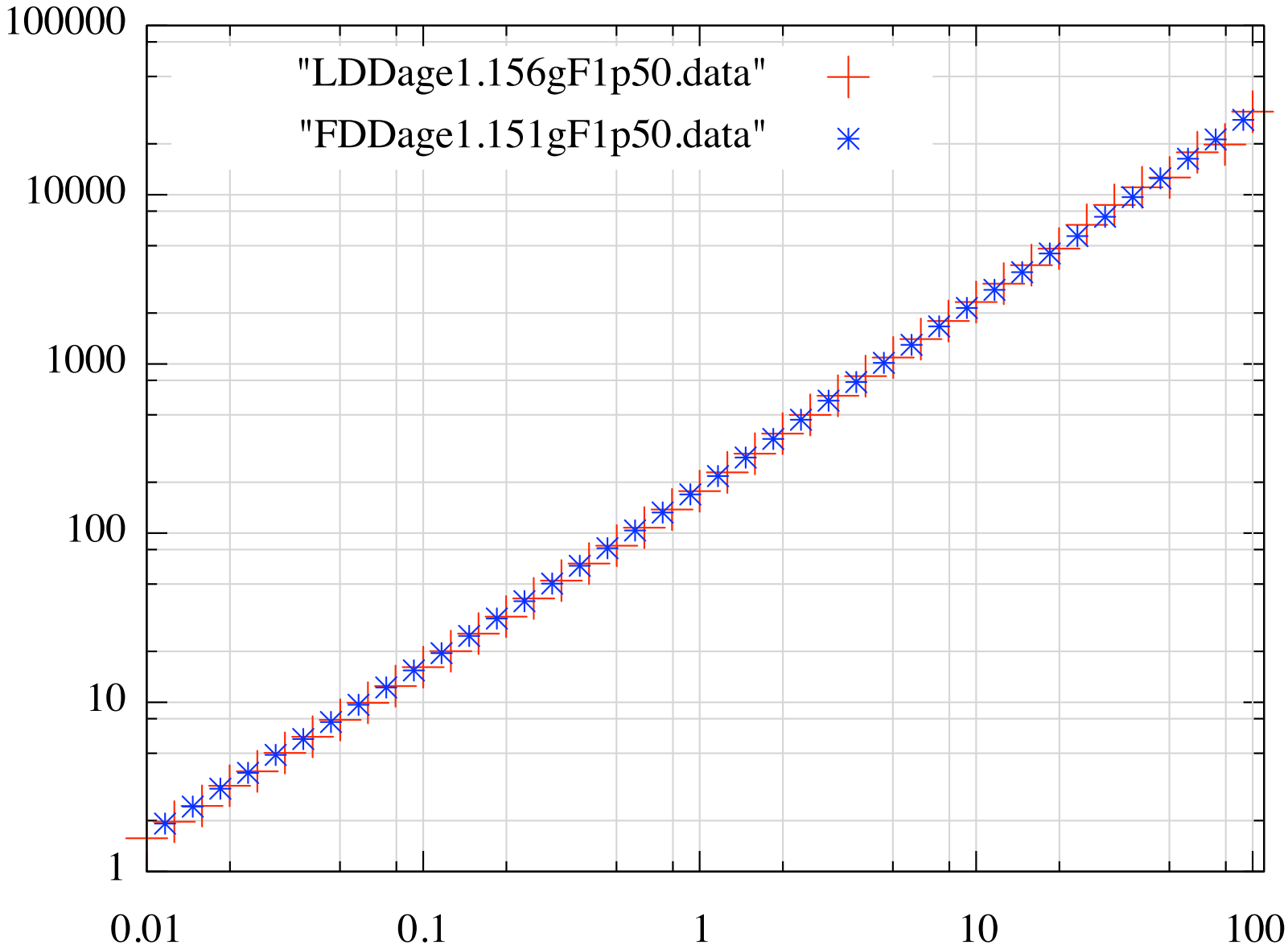


LDD vs FDD 2
FDD(956g/cm2) is geometrically sclaed to LDD height.
gamma F1: LDD mu=86m age=1.156 FDD mu=79.6 age=1.151

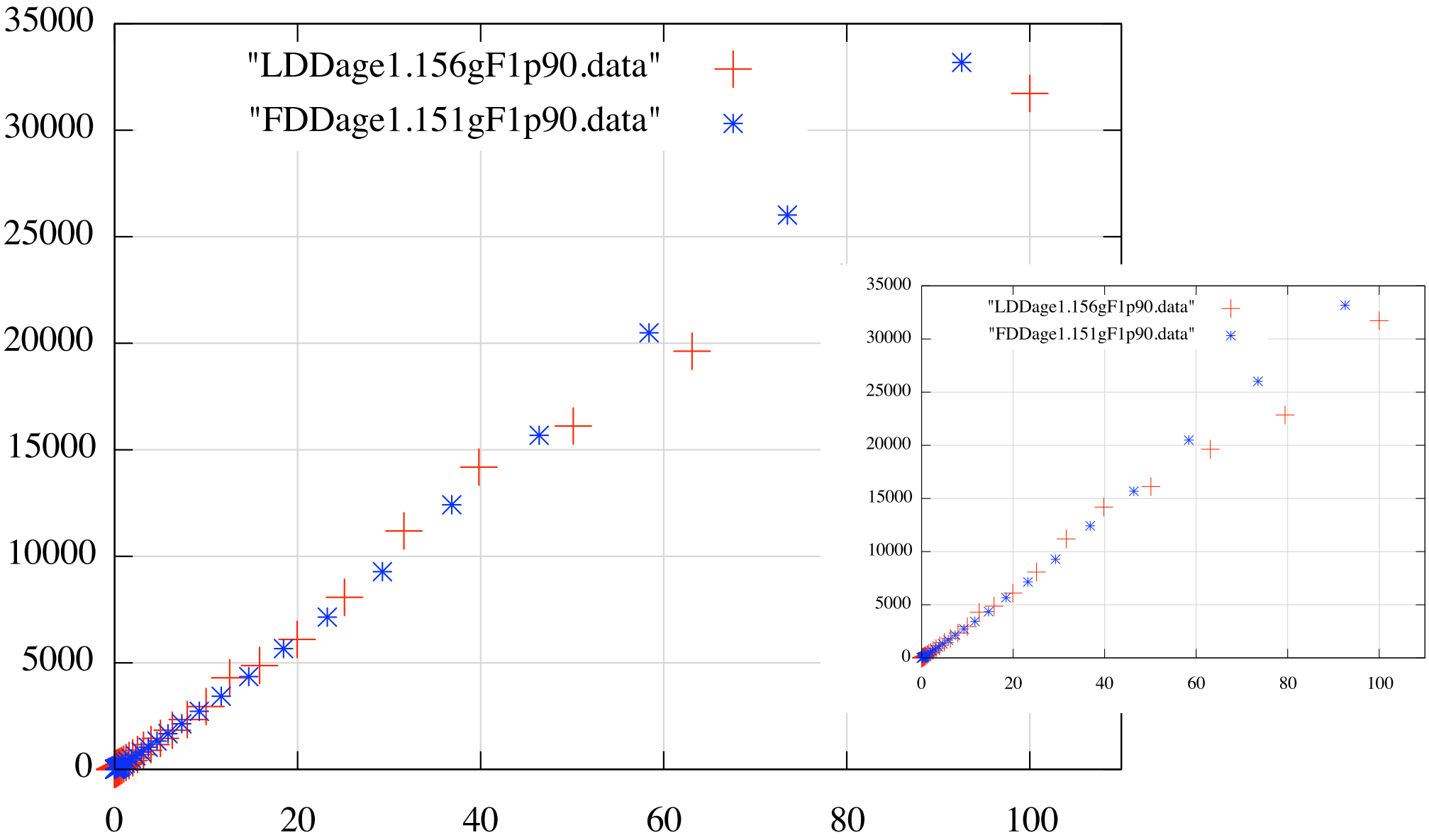


LDD vs FDD 2
gamma F1

T50%

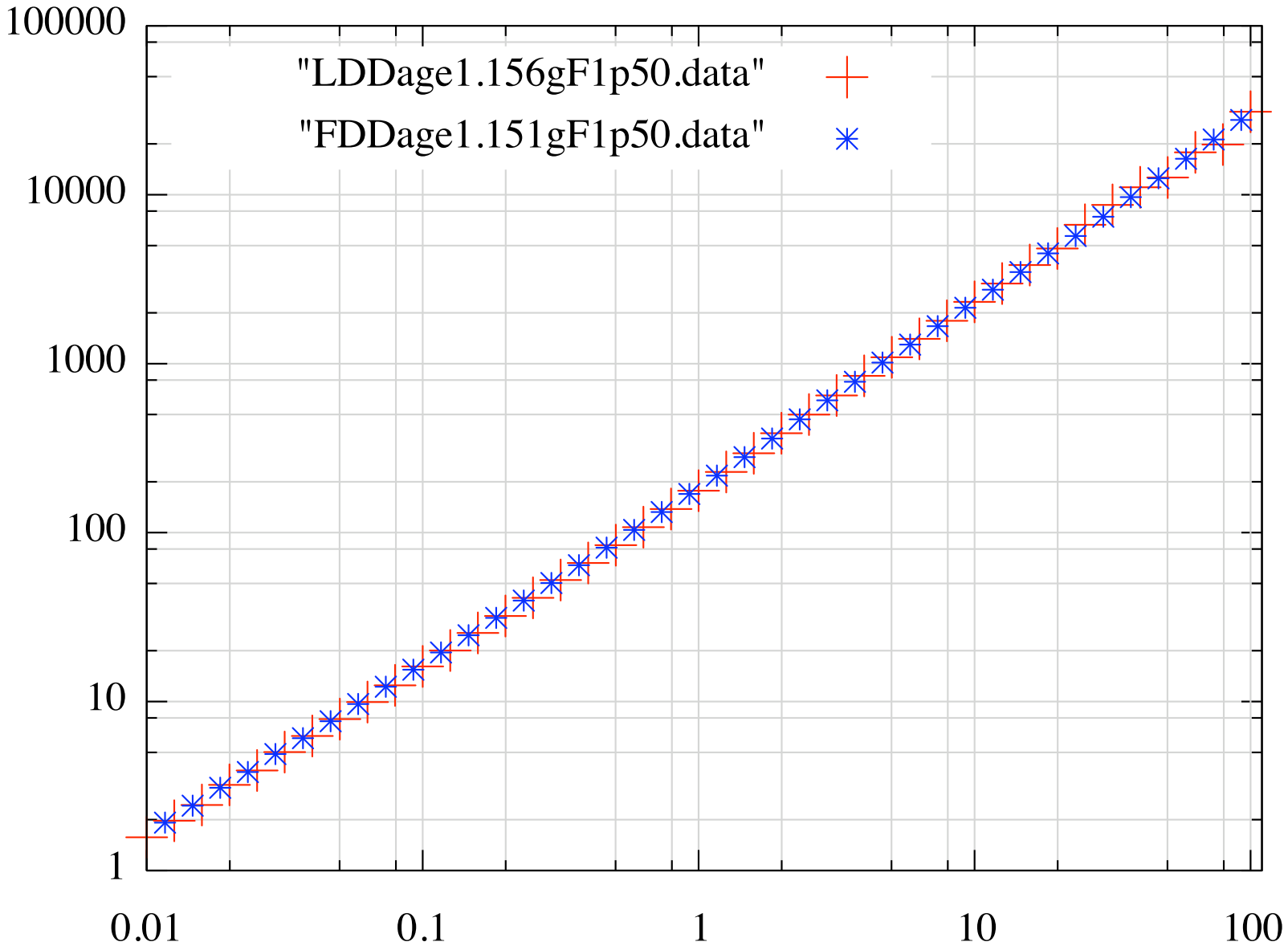


LDD vs FDD 2
gamma F1
T90%



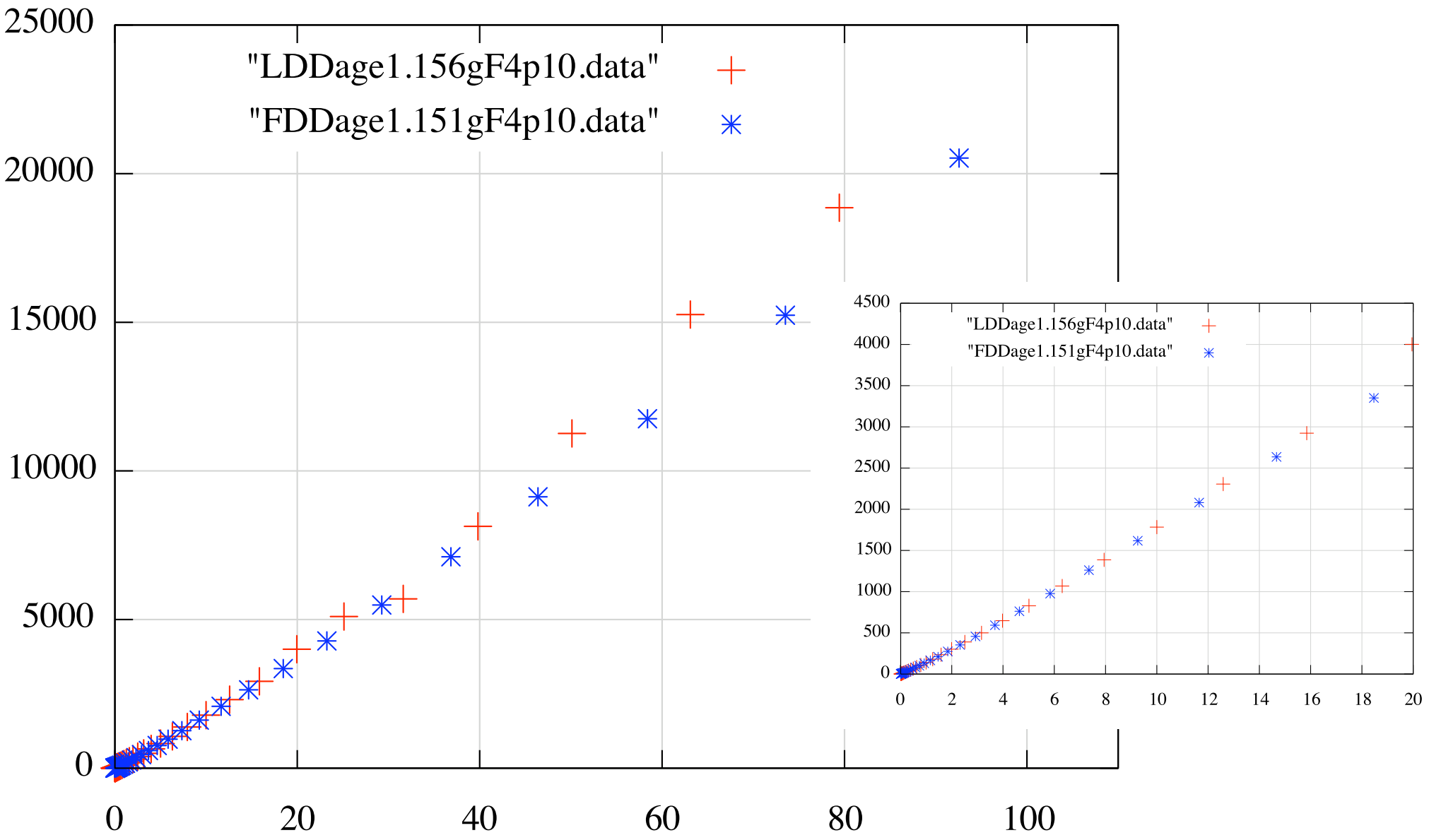
LDD vs FDD 2
gamma F1

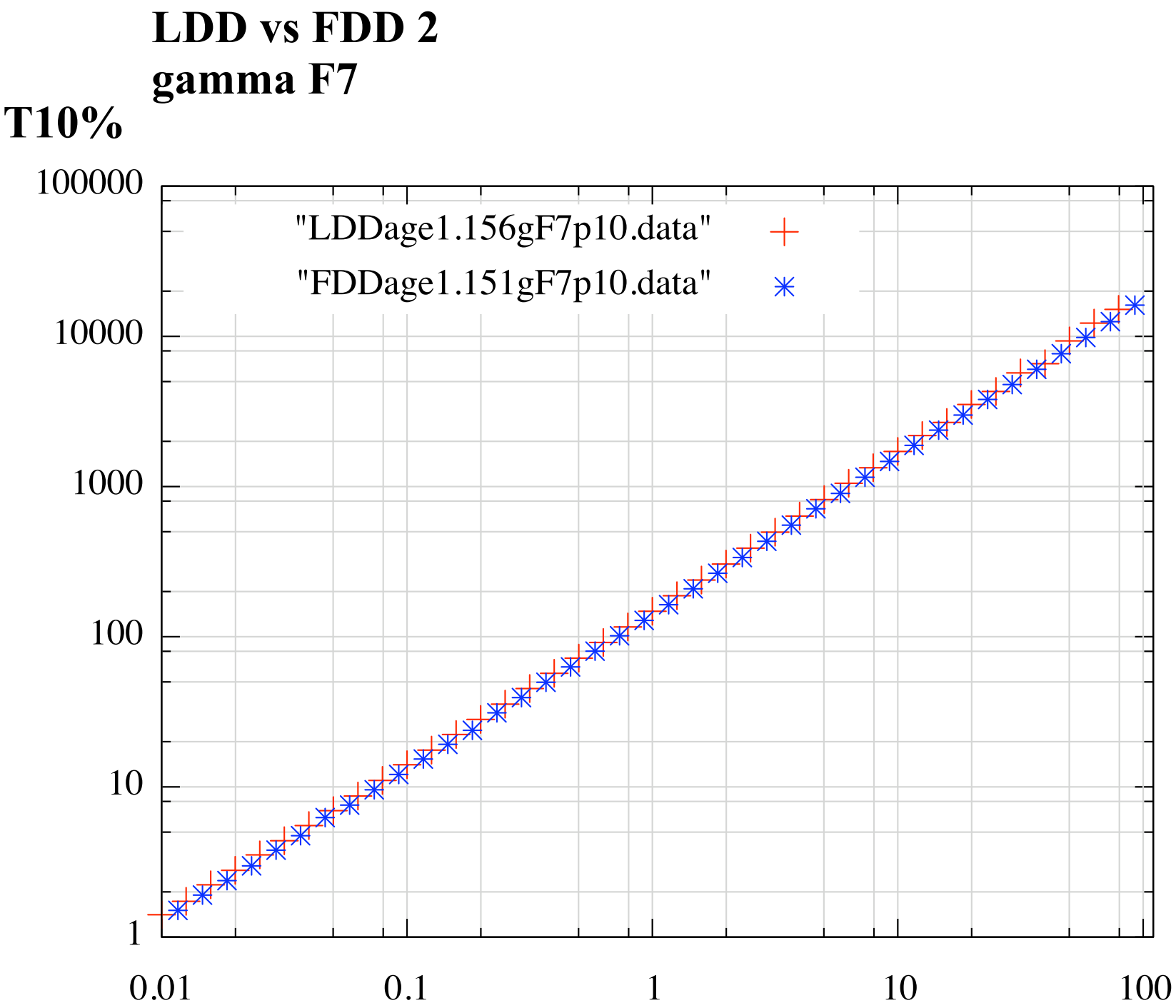
T90%

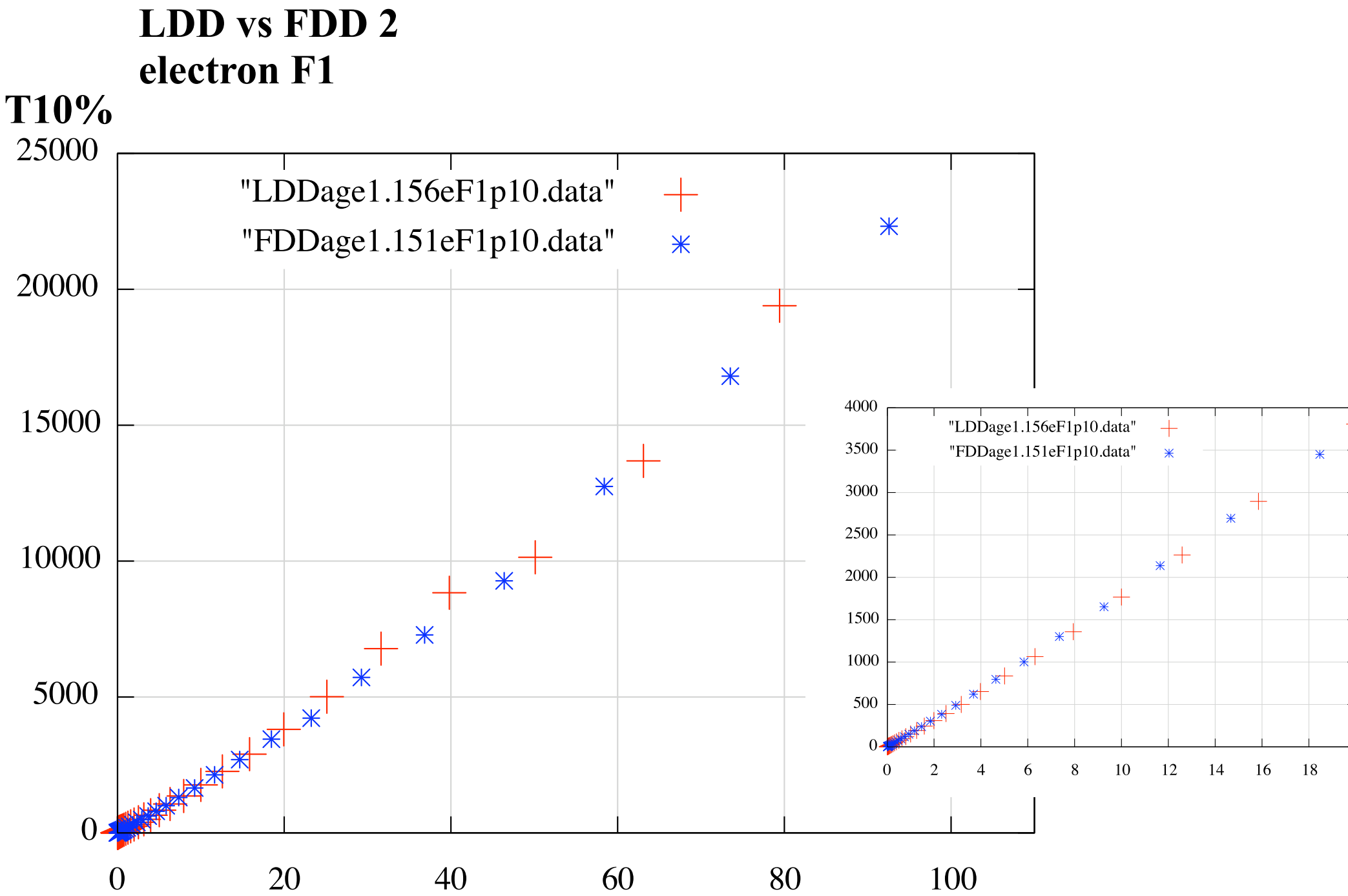


LDD vs FDD 2
gamma F4

T10%

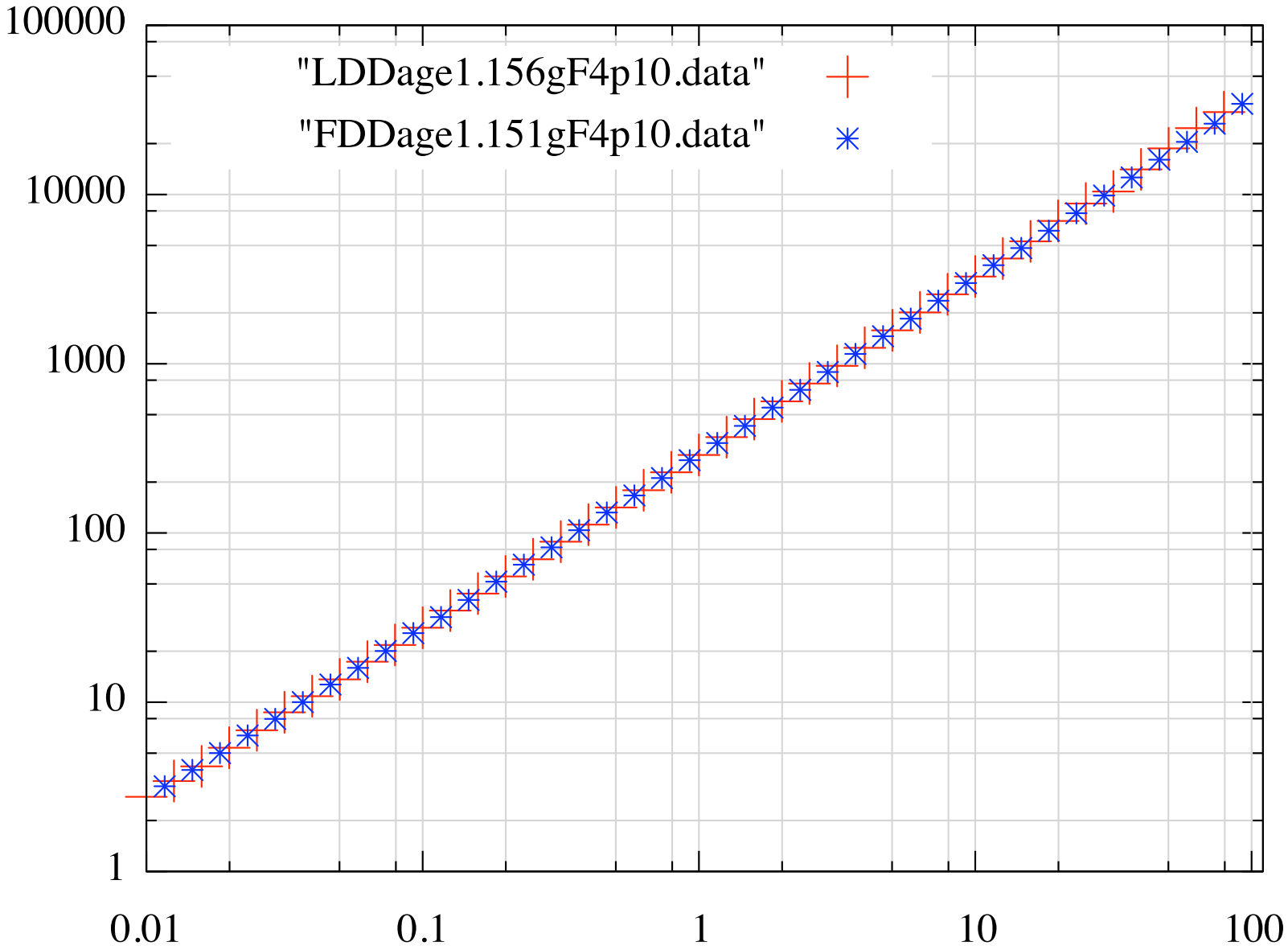



LDD vs FDD 2
gamma F7
T10%
100000
10000
1000
100
10
1
0.01
0.1
1
10
100
"LDDage1.156gF7p10.data"
"FDDage1.151gF7p10.data"


LDD vs FDD 2
electron F1
T10%
"LDDage1.156eF1p10.data"
"FDDage1.151eF1p10.data"
25000
20000
15000
10000
5000
0
0
20
40
60
80
100
4000
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
14
16
18

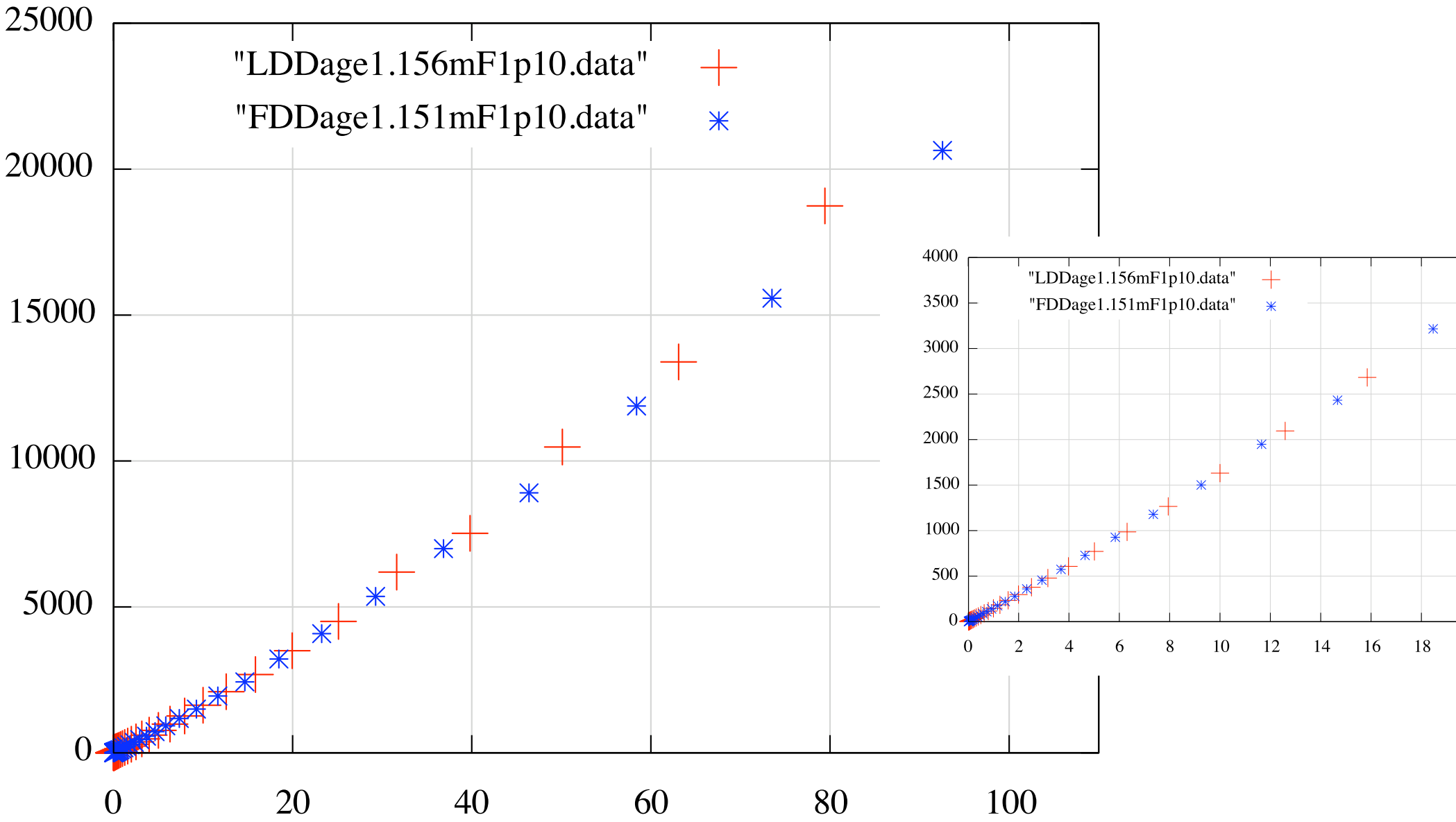
LDD vs FDD 2
electron F1

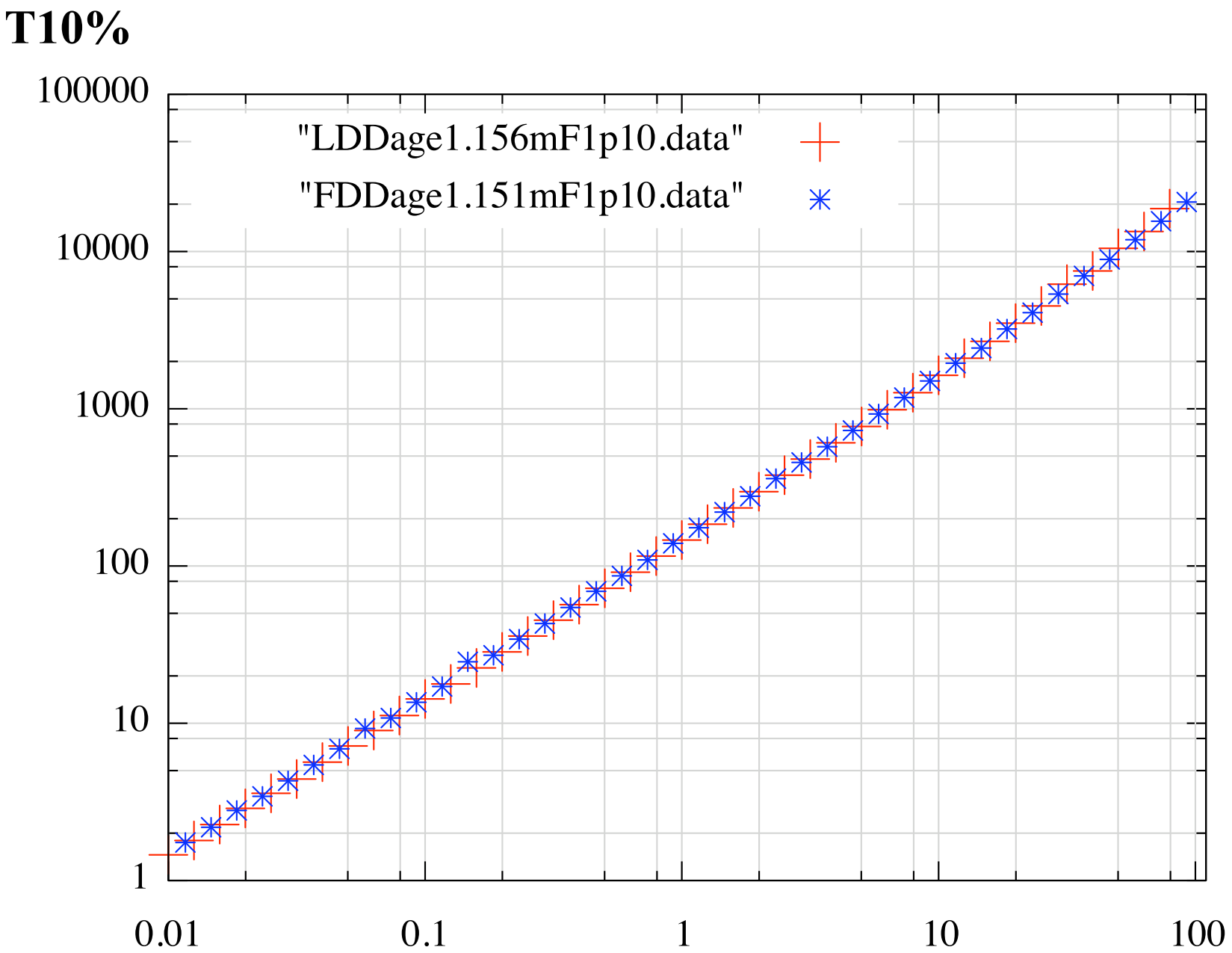
T10%



LDD vs FDD 2
muon F1

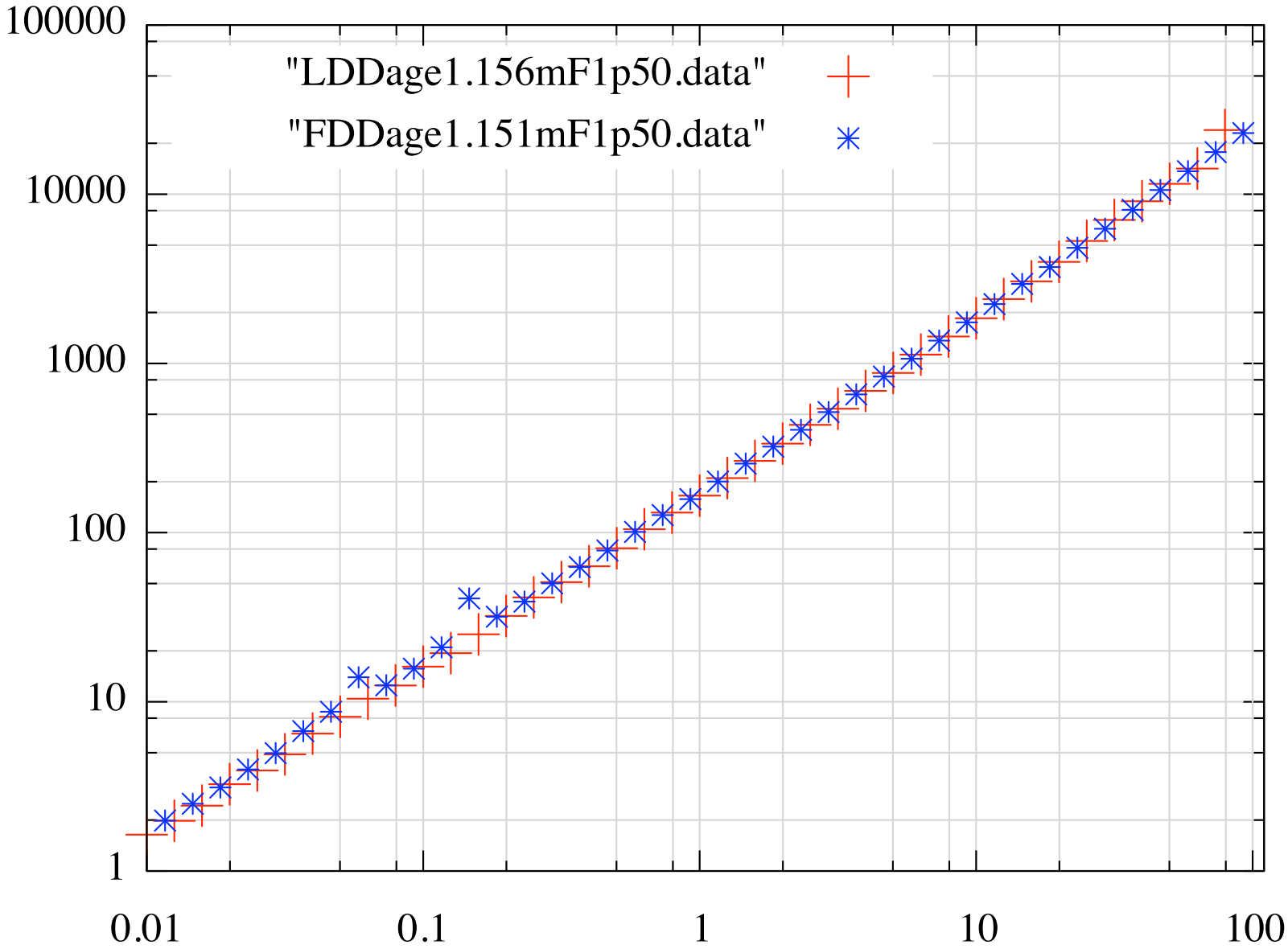
T10%




LDD vs FDD 2
muon F1
T10%
100000
10000
1000
100
10
1
0.01
0.1
1
10
100
"LDDage1.156mF1p10.data"
"FDDage1.151mF1p10.data"

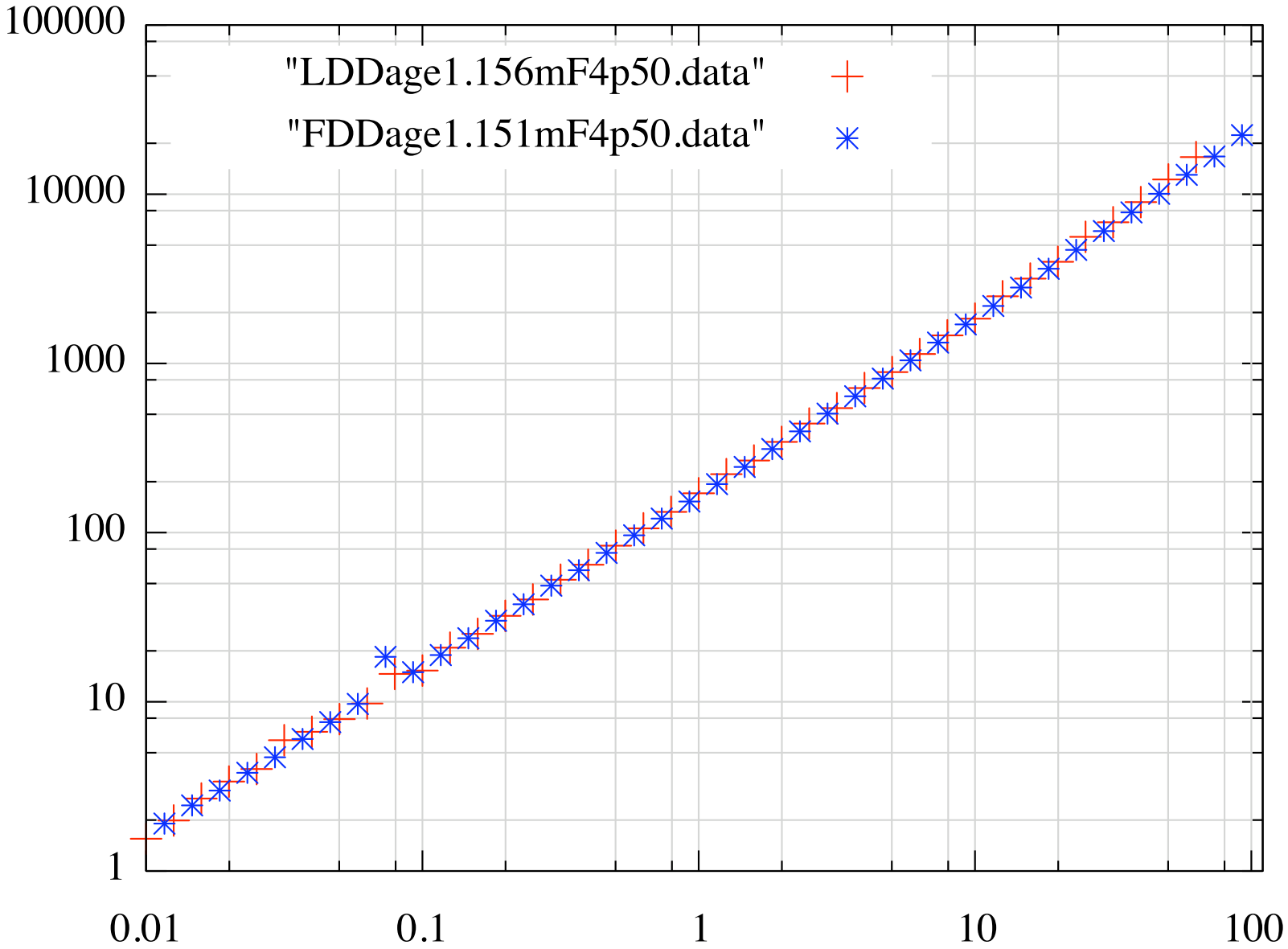
LDD vs FDD 2
muon F1

T50%

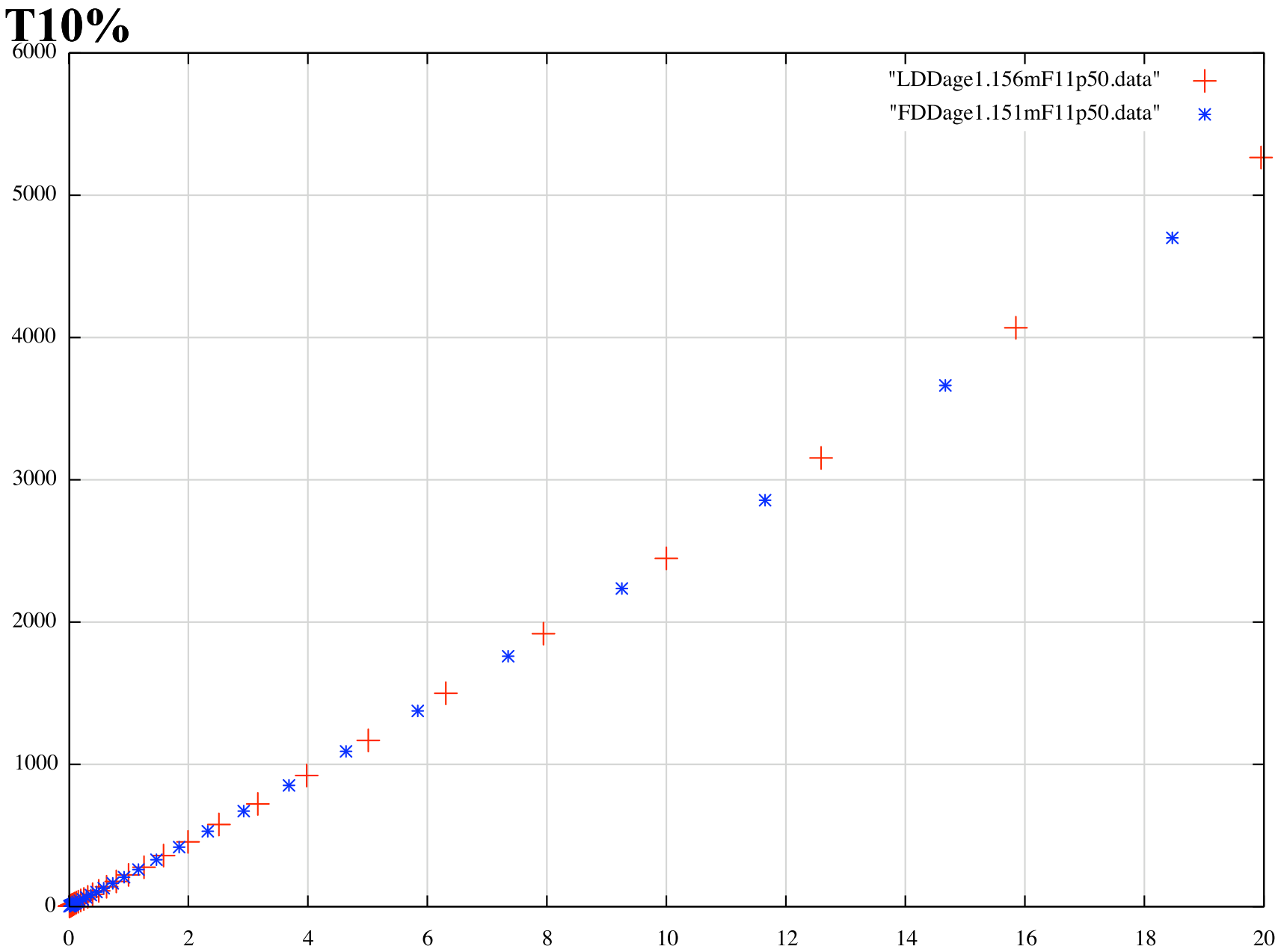


LDD vs FDD 2
muon F4

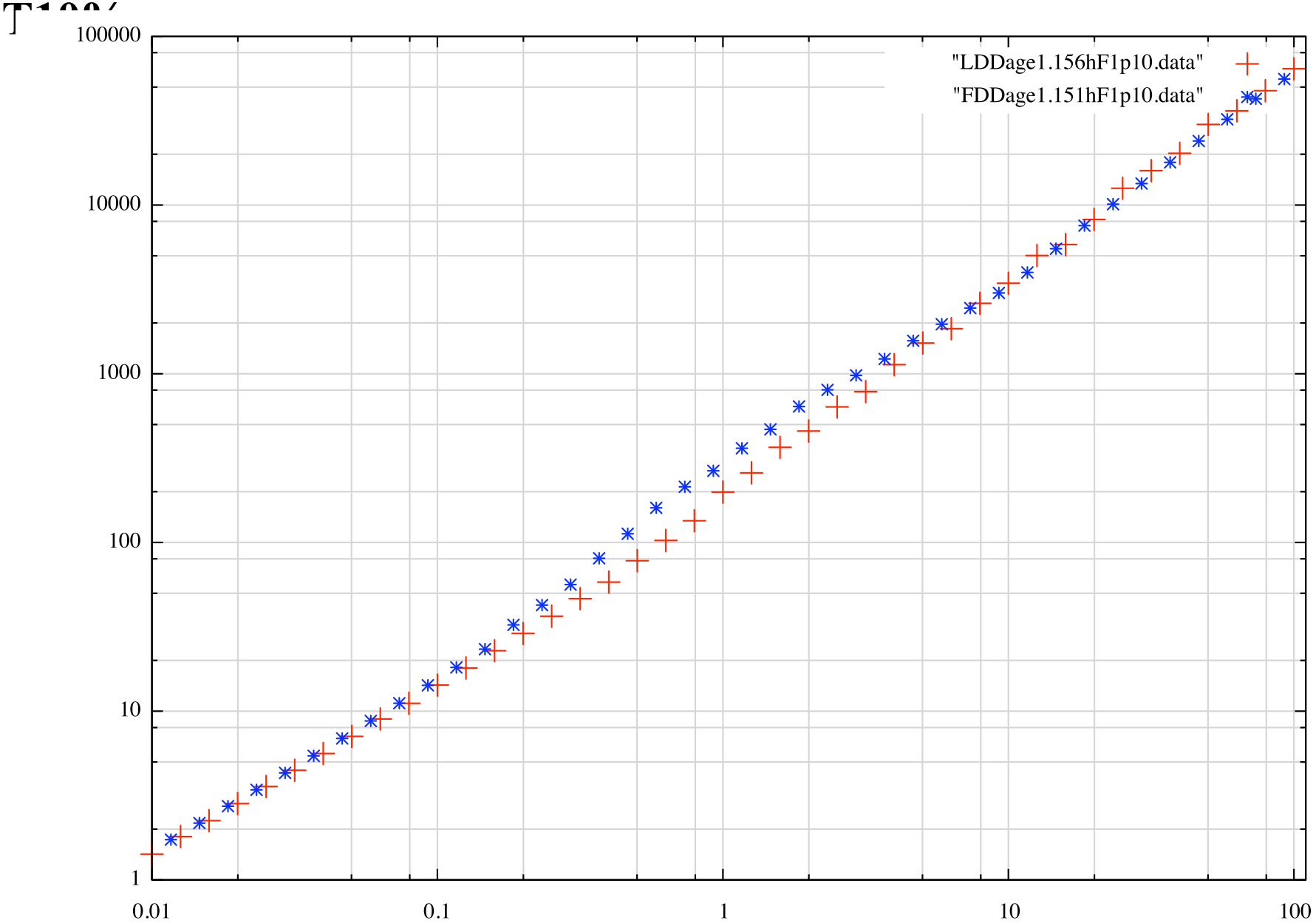
T50%

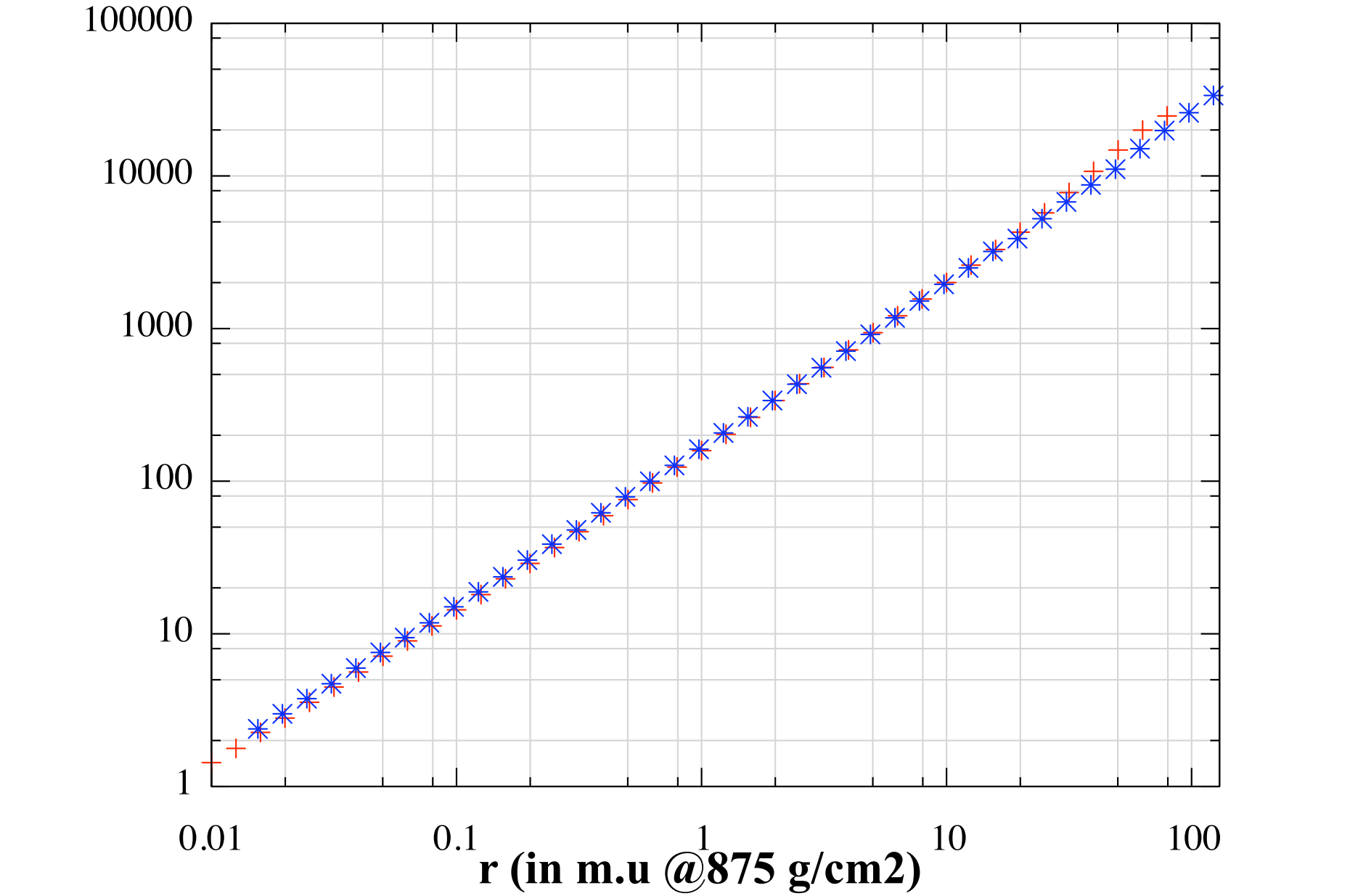


LDD vs FDD 2
hadron F1

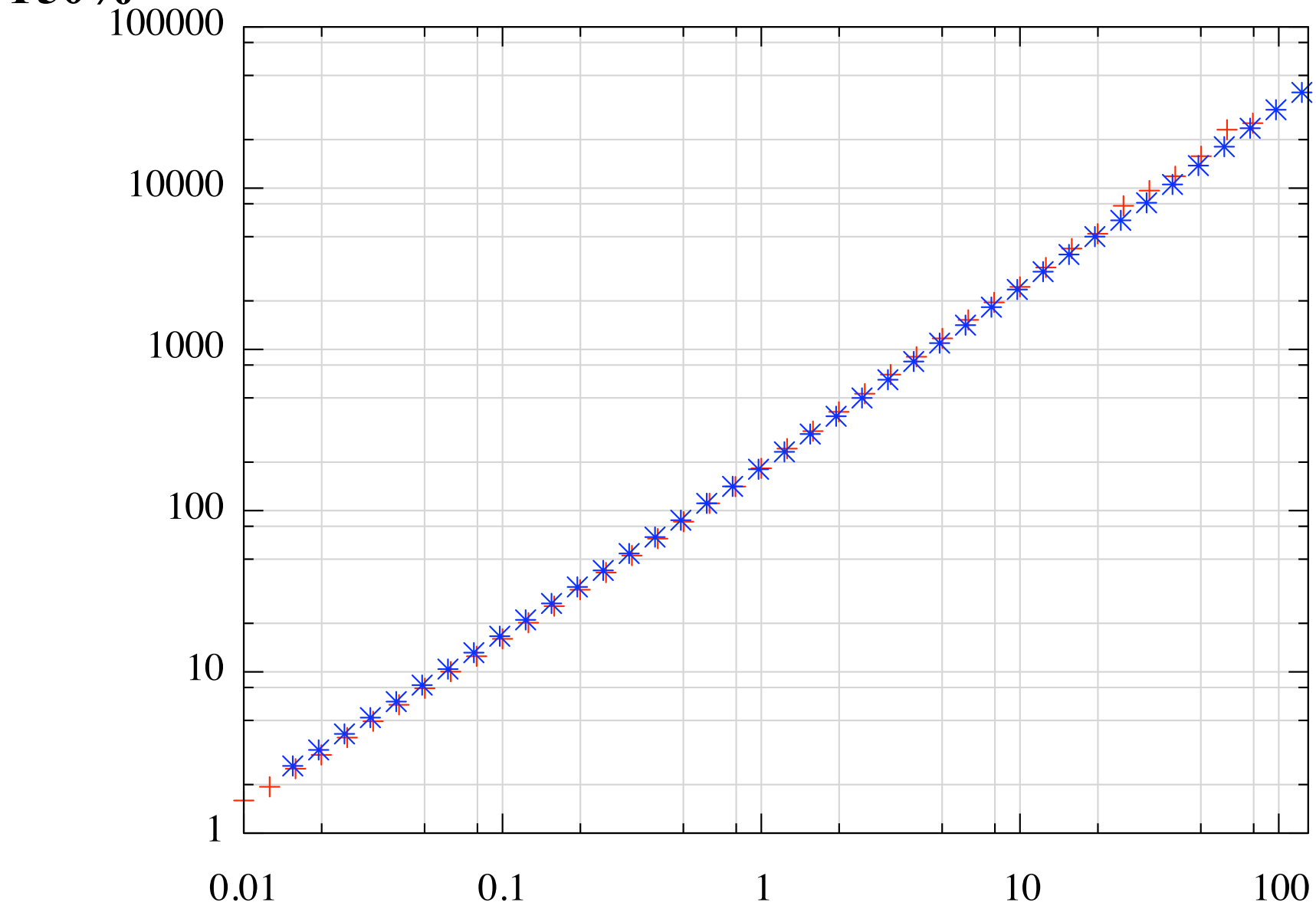


LDD vs FDD 2
hadron F1

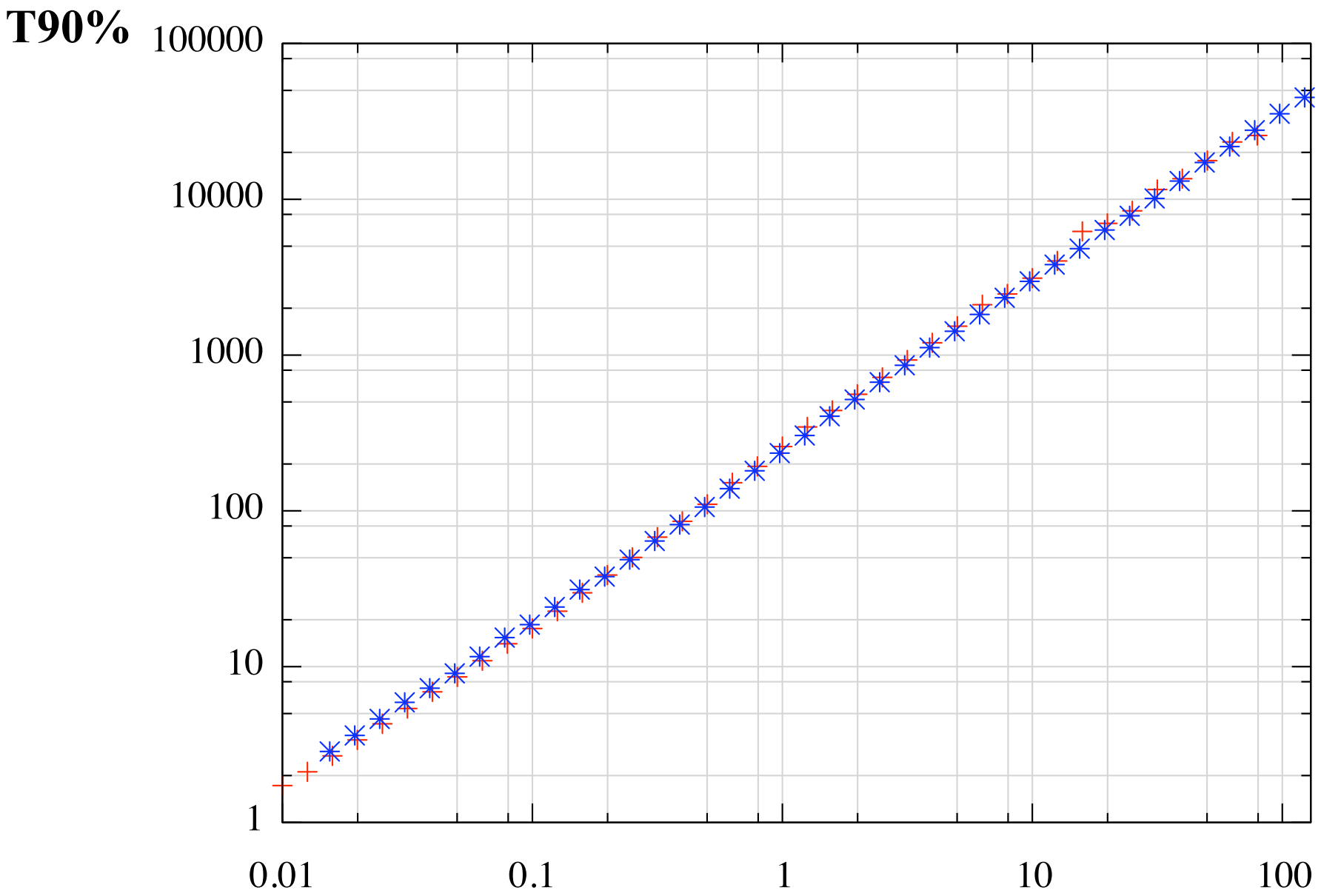


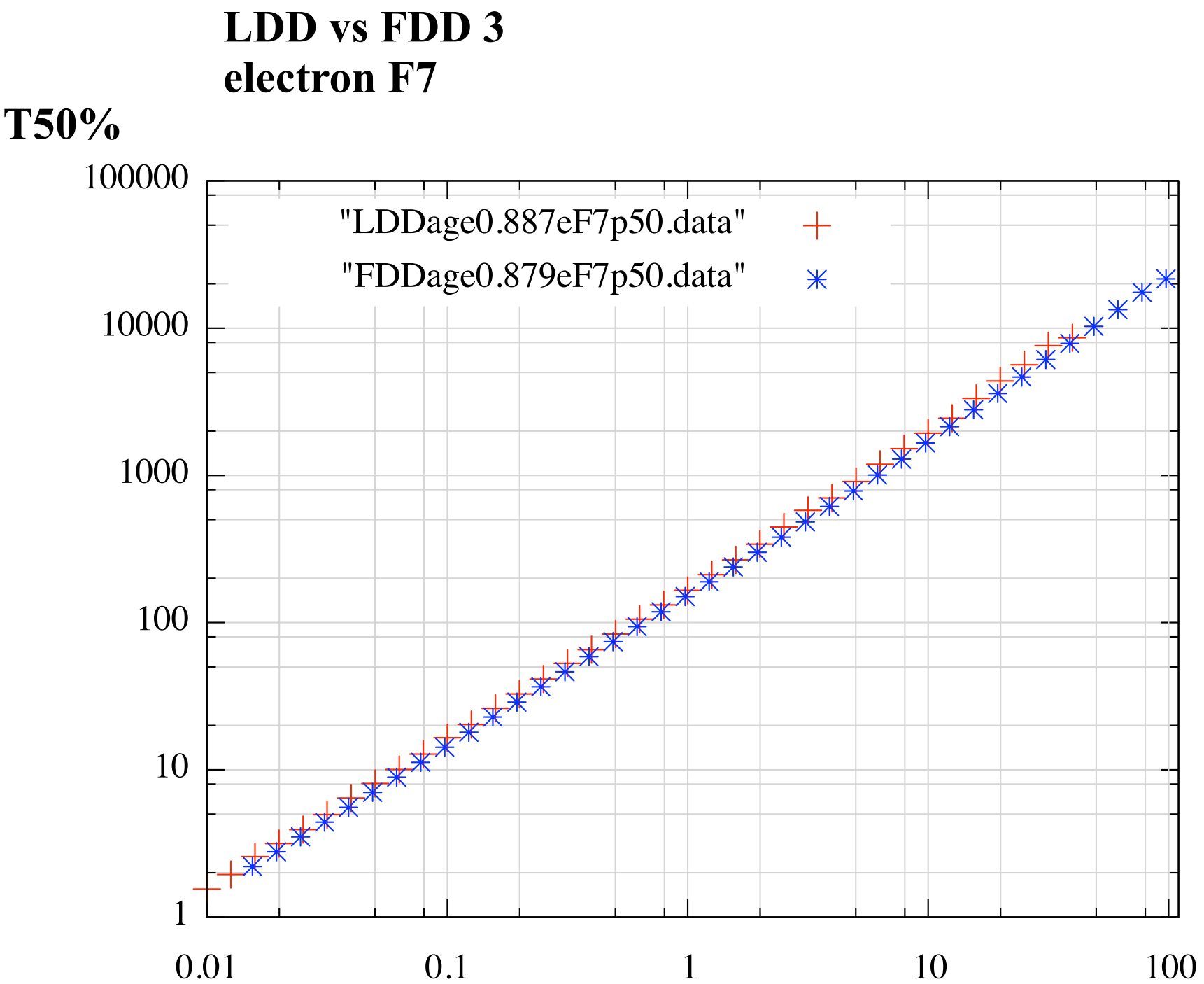

LDD vs FDD 3
gamma F1
LDD: age=0.887 cog=0.789 firstz=305
FDD ly age mu depth cog
12 0.879 133. 531.3 0.706
T10%(ns)
100000
10000
1000
100
10
1
0.01
0.1
1
10
100
r (in m.u @875 g/cm2)

LDD vs FDD 3
gamma F1

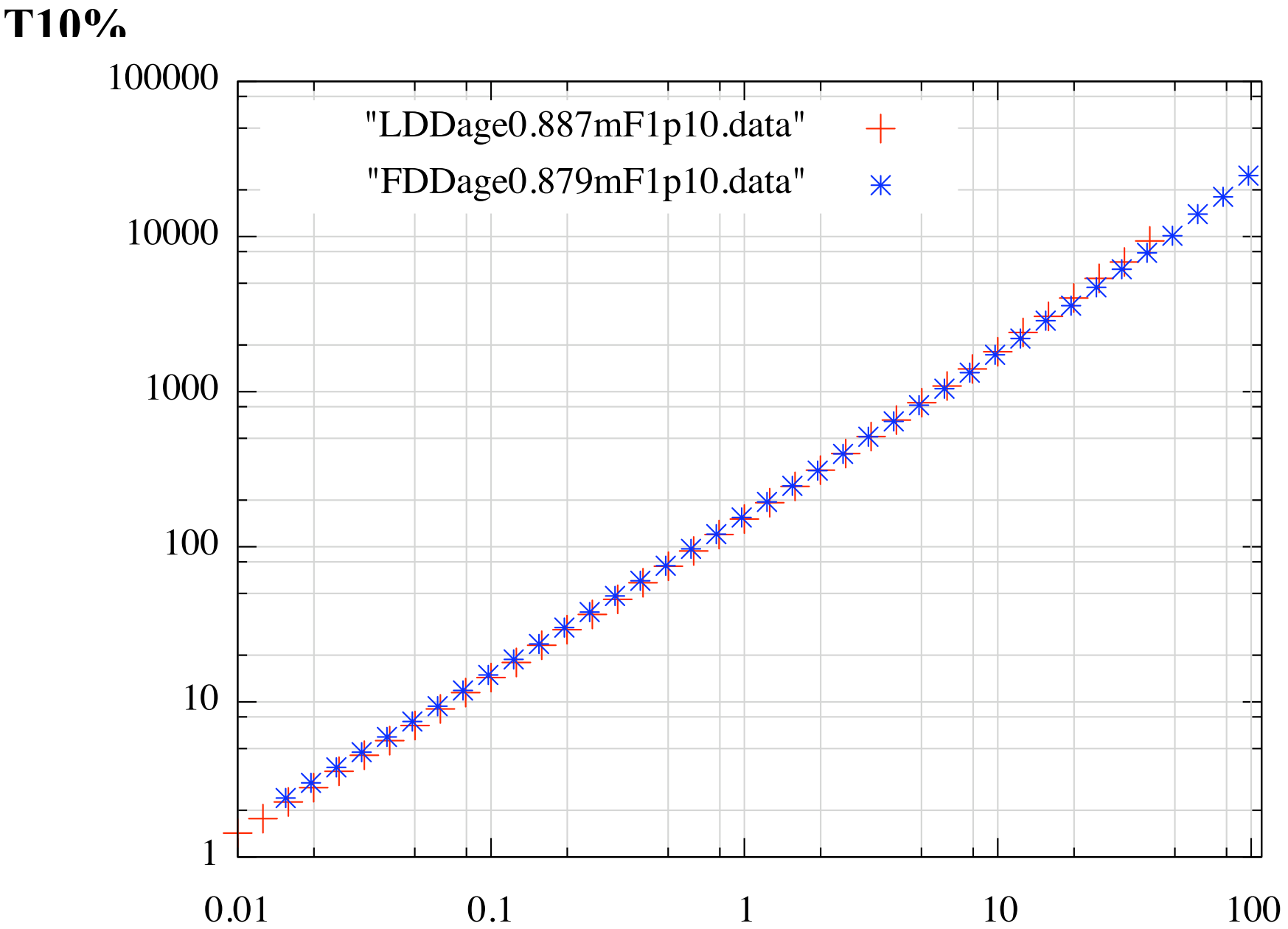


LDD vs FDD 3
gamma F1



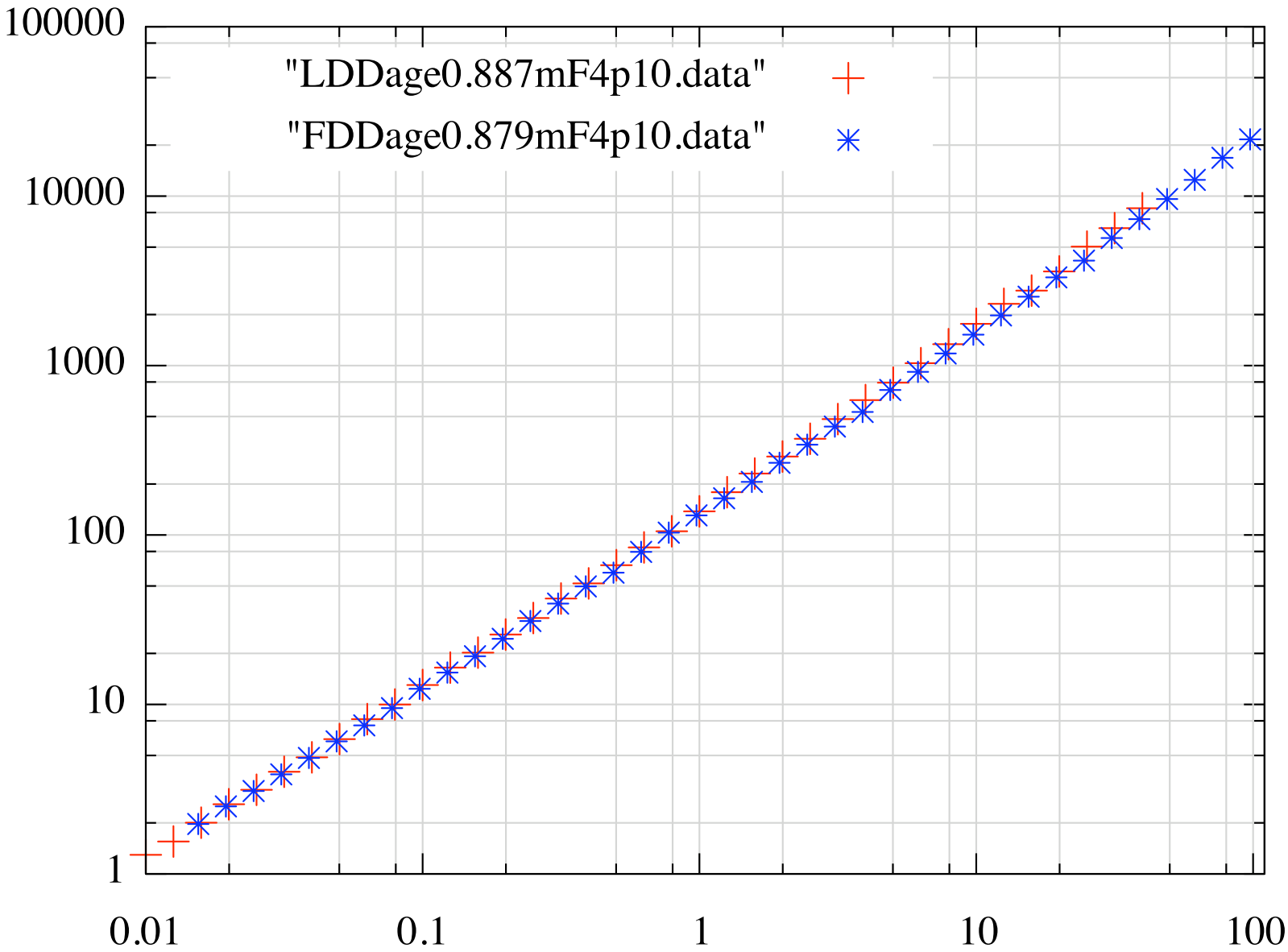

LDD vs FDD 3
electron F7
T50%
"LDDage0.887eF7p50.data"
"FDDage0.879eF7p50.data"
100000
10000
1000
100
10
1
0.01
0.1
1
10
100

LDD vs FDD 3
muon F1



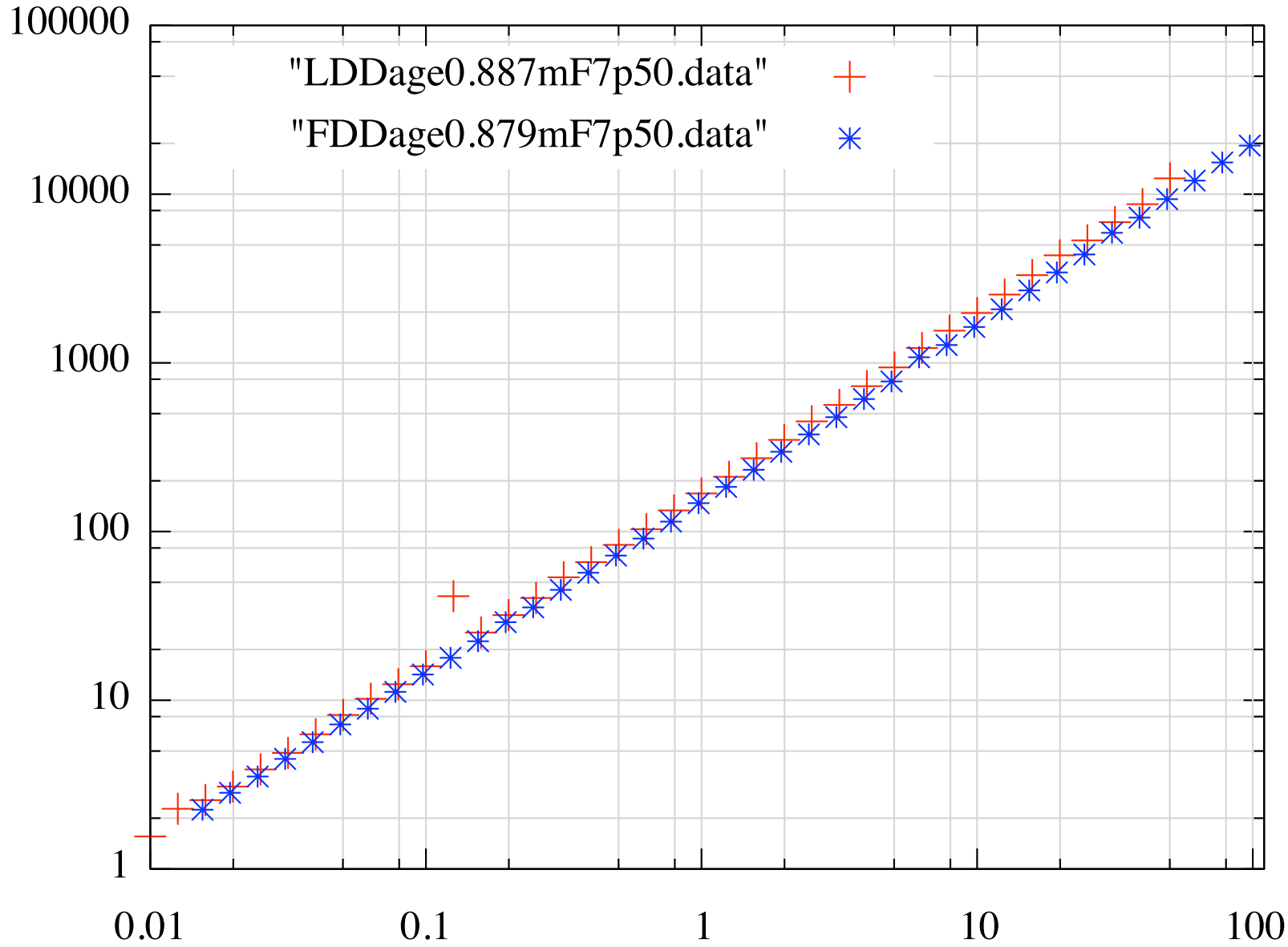
LDD vs FDD 3
muon F4

T10%



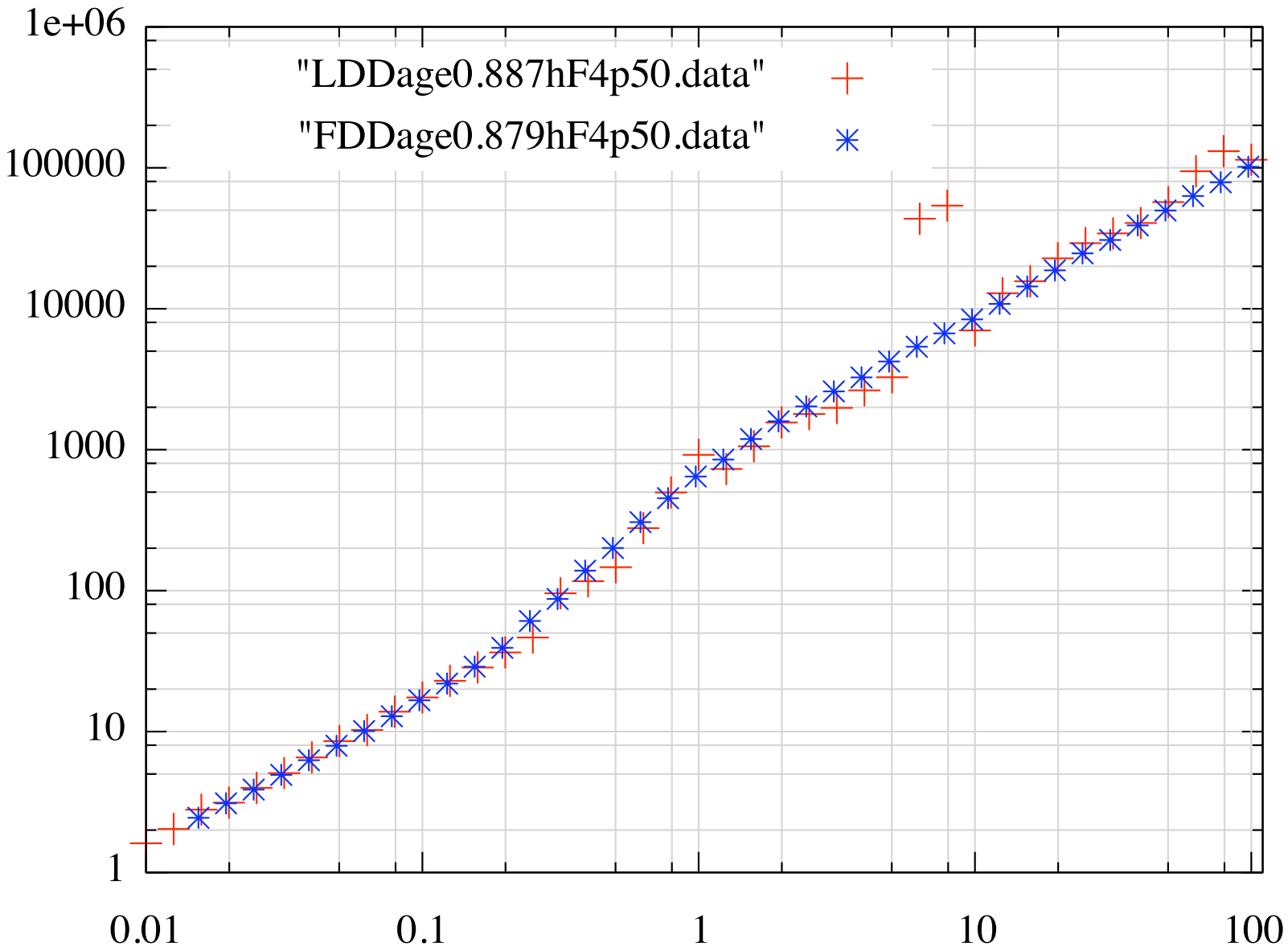
LDD vs FDD 3
muon F7

T50%

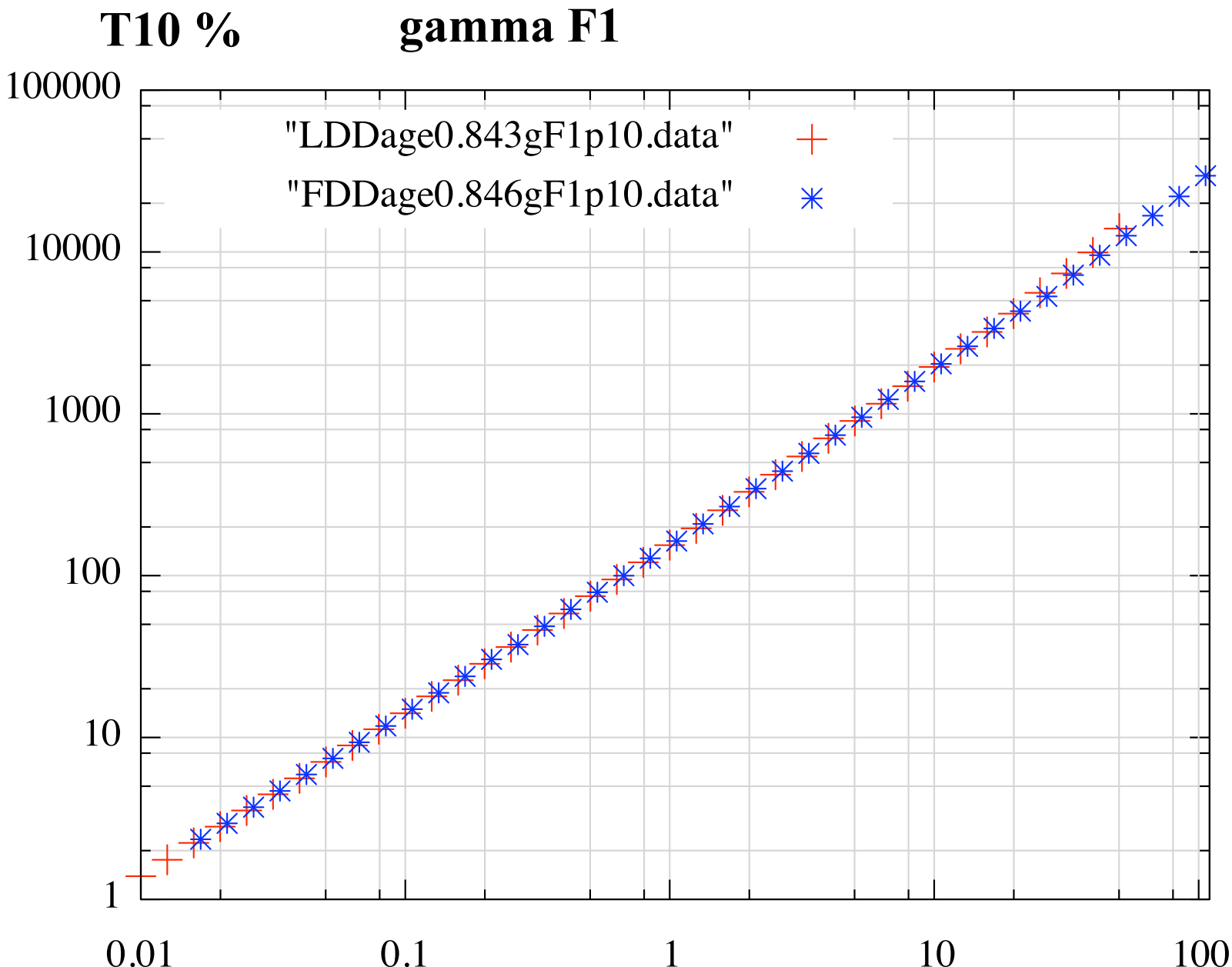


LDD vs FDD 3
hadron F4

T50%

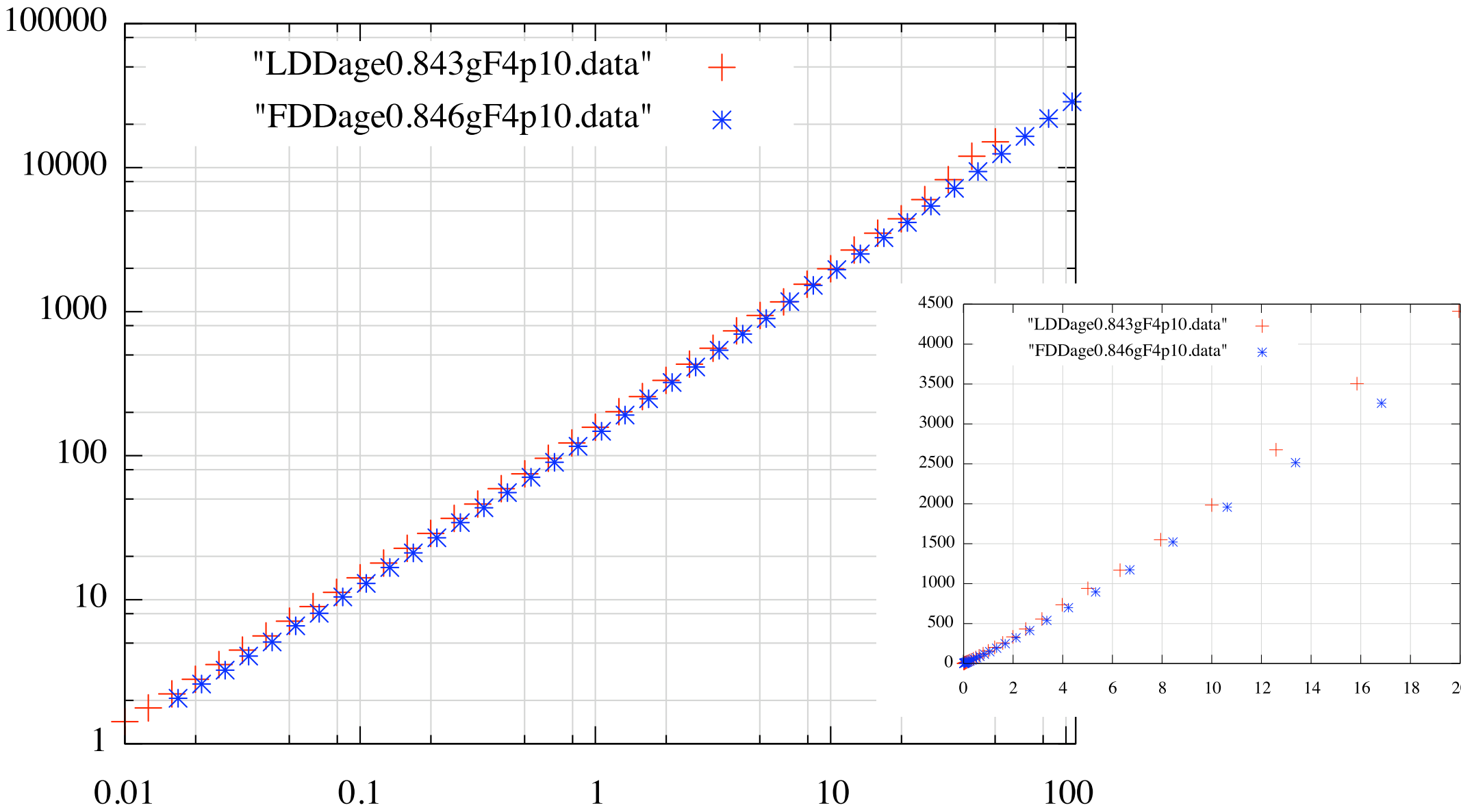


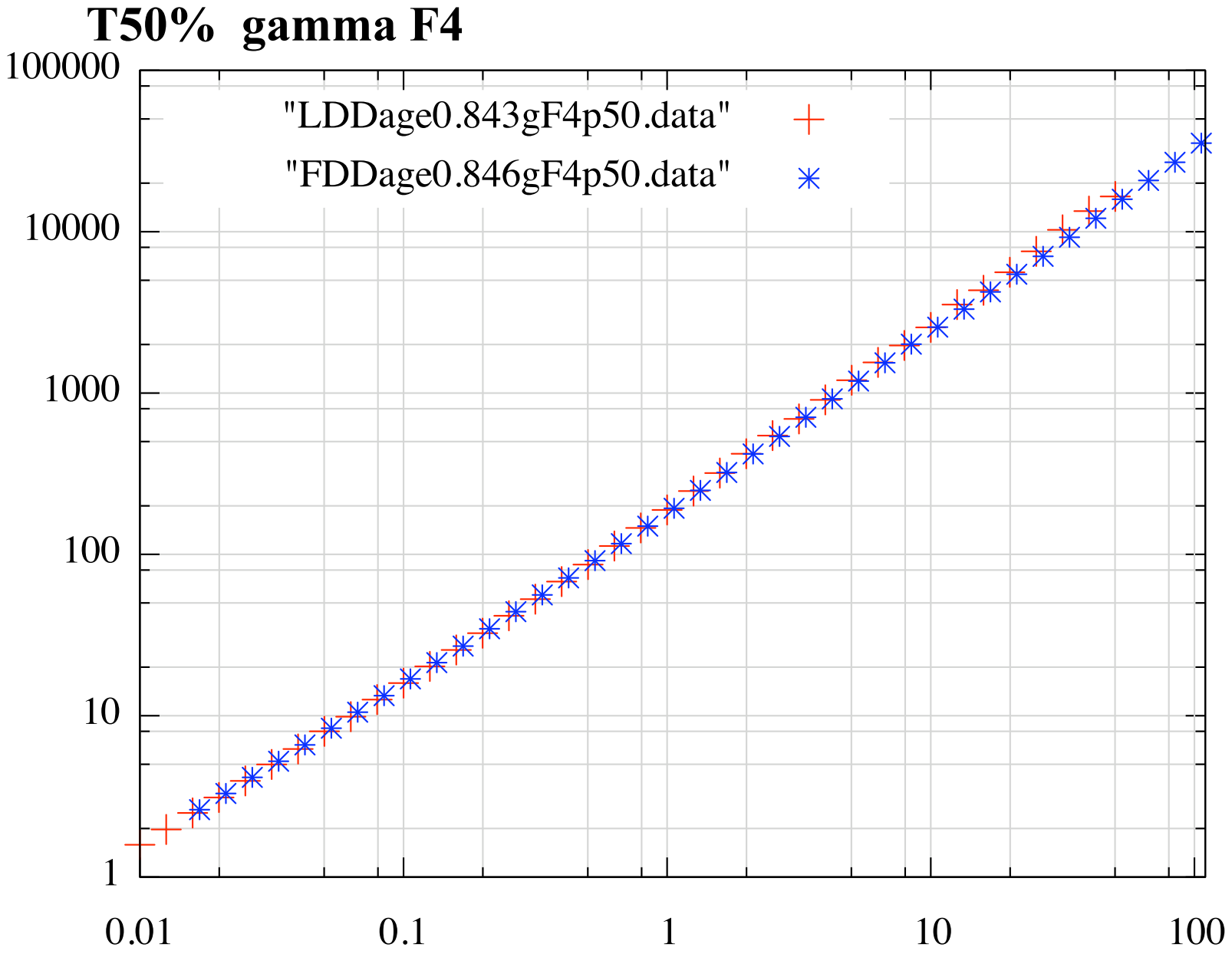
LDD vs FDD 4: LDD starting height=8km. age at 875 g/cm2=0.843
FirstCol=382 g/cm2
FDD age 0.846 @ depth 488 g/cm2.

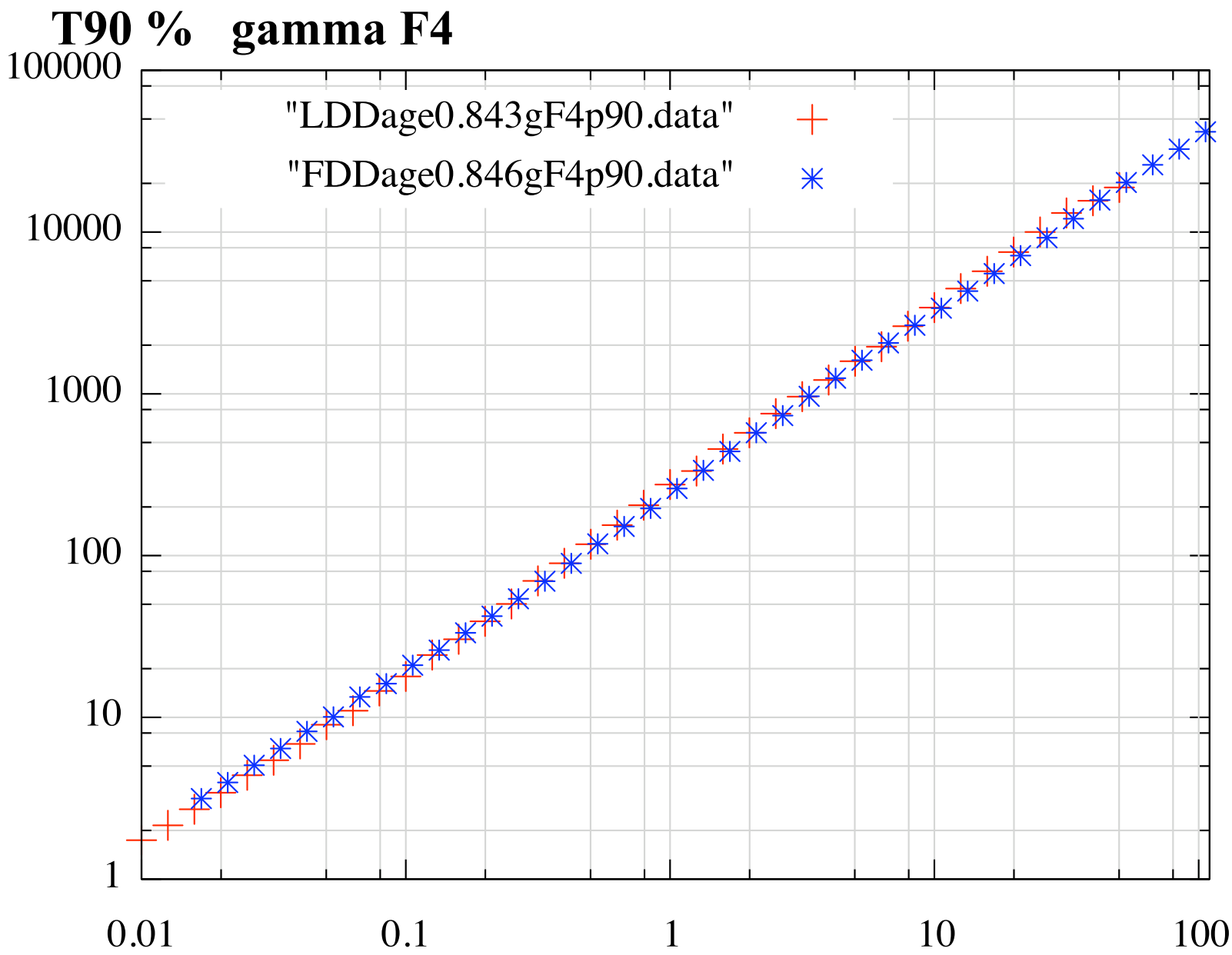


ibid

T10% gamma F4

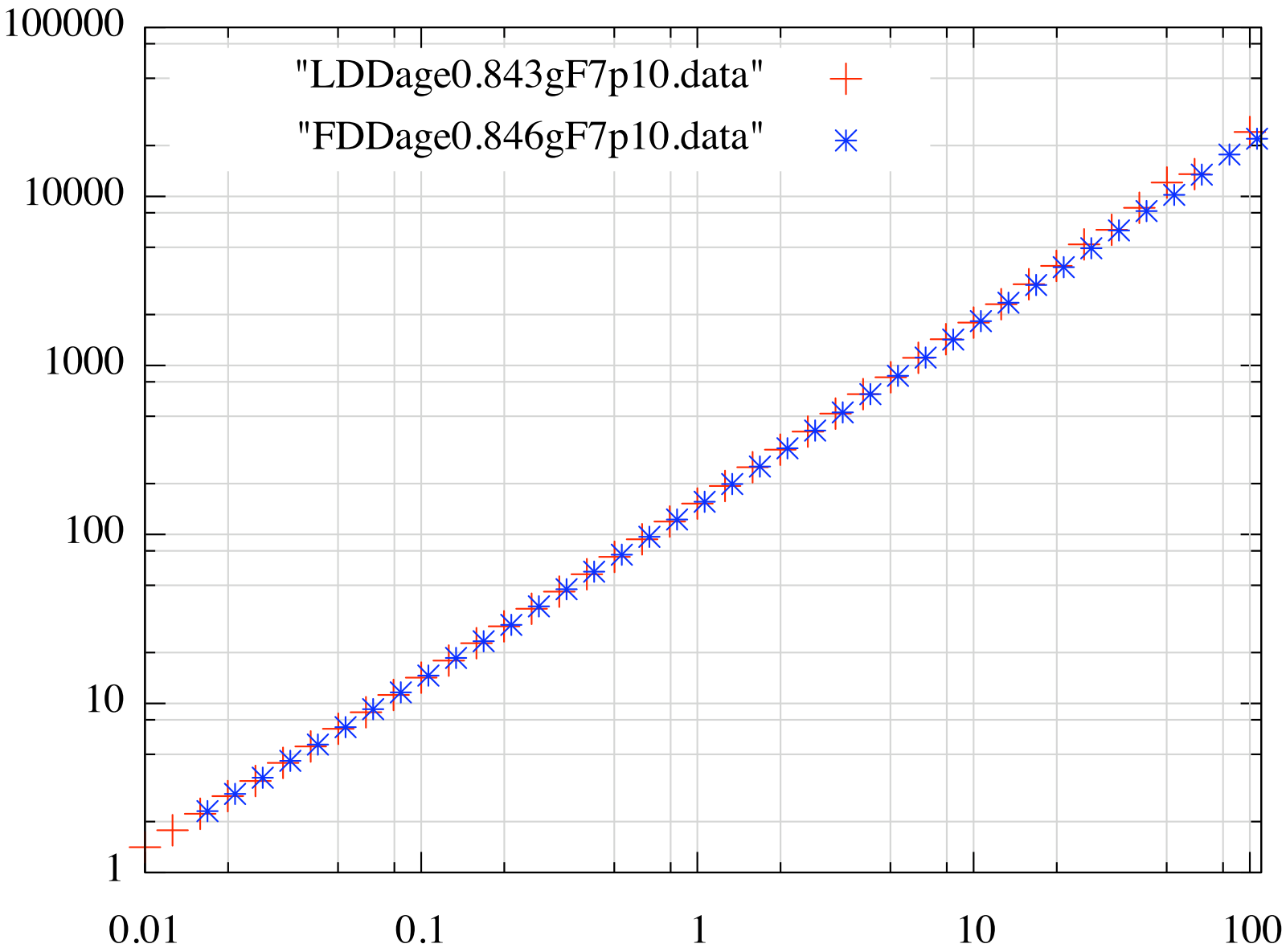



T50% gamma F4
"LDDage0.843gF4p50.data"
"FDDage0.846gF4p50.data"
100000
10000
1000
100
10
1
0.01
0.1
1
10
100

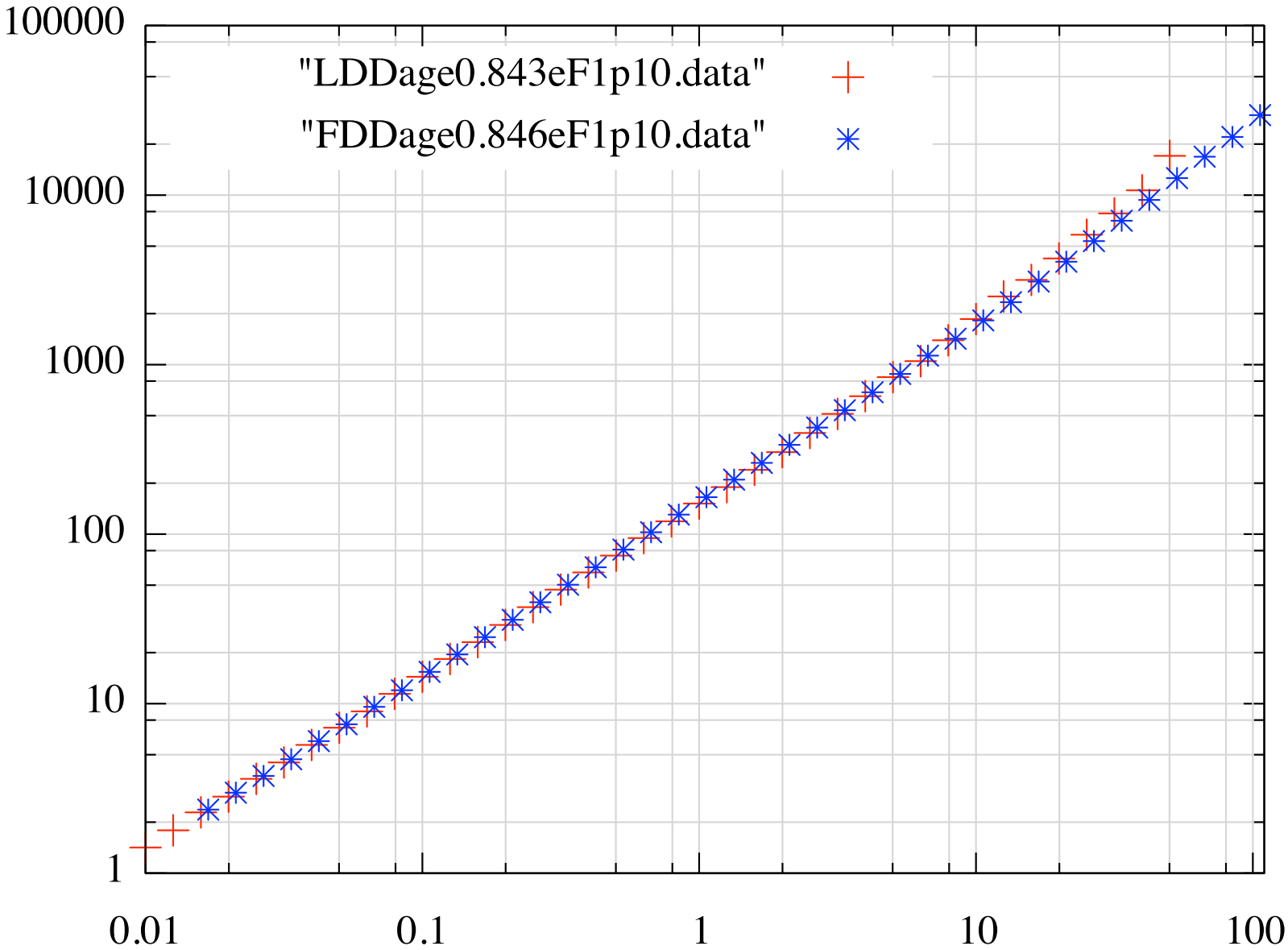

T90 % gamma F4
"LDDage0.843gF4p90.data"
"FDDage0.846gF4p90.data"
100000
10000
1000
100
10
1
0.01
0.1
1
10
100

ibid

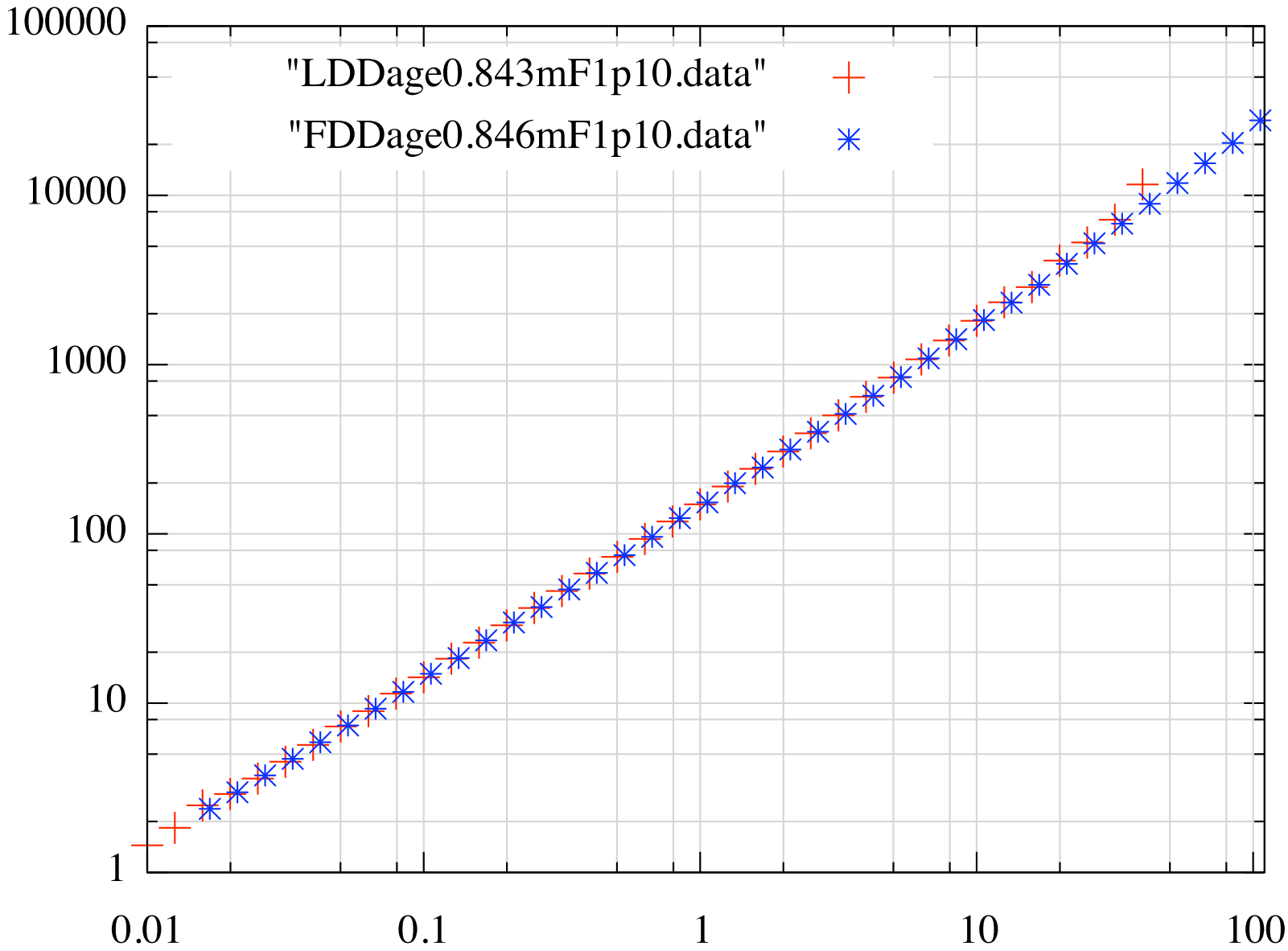
T10 % **gamma F7**

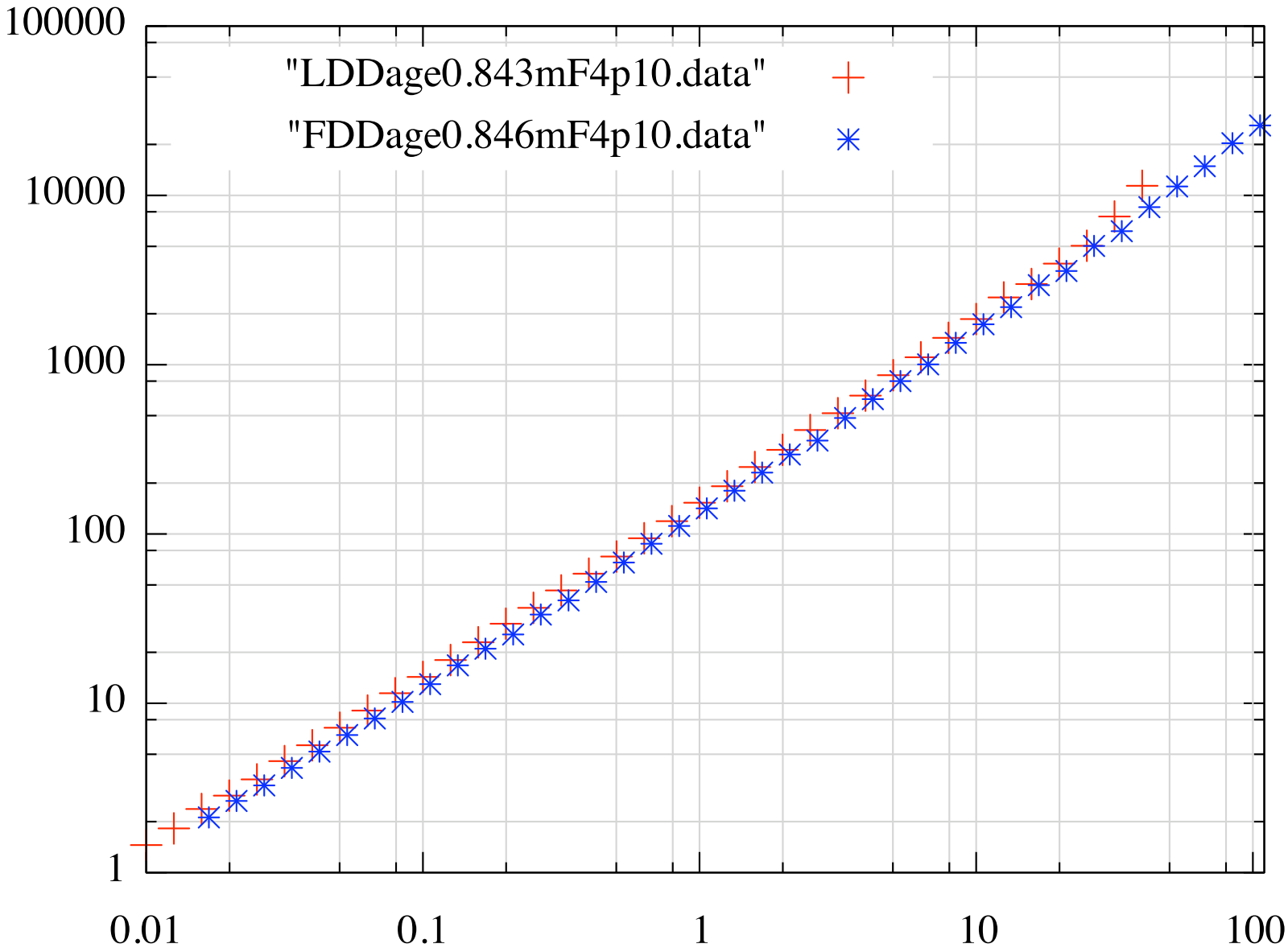


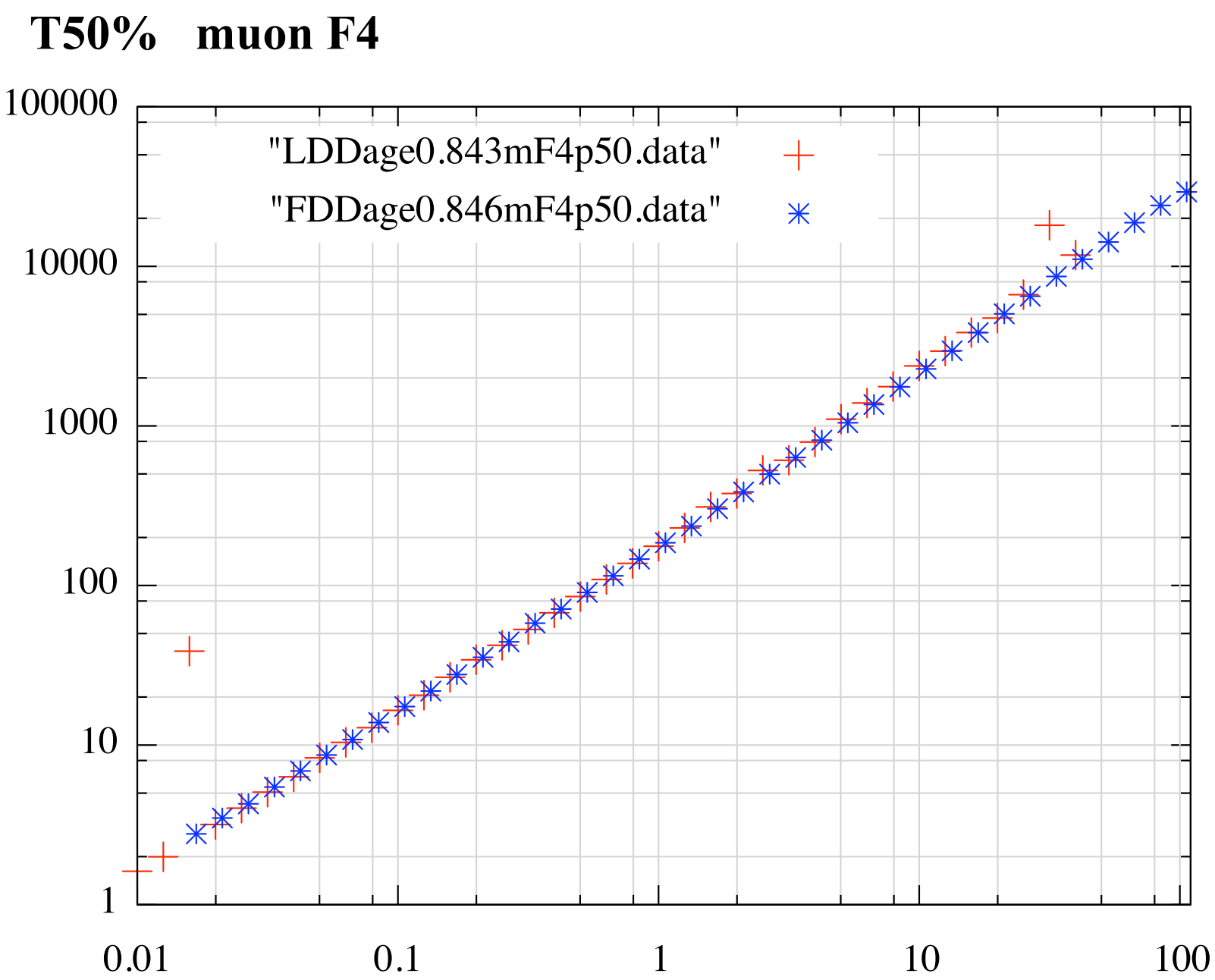
T10% electron F1

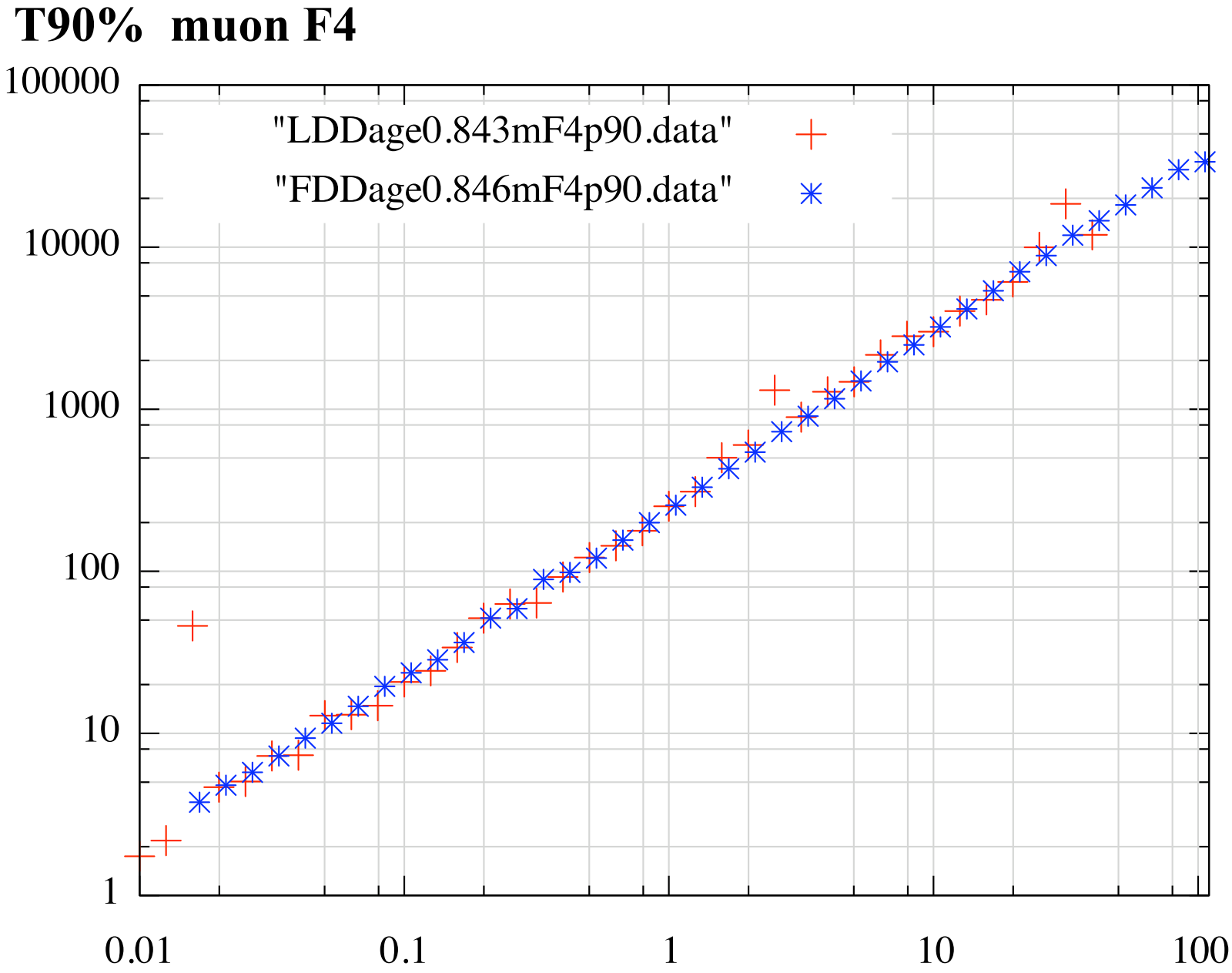


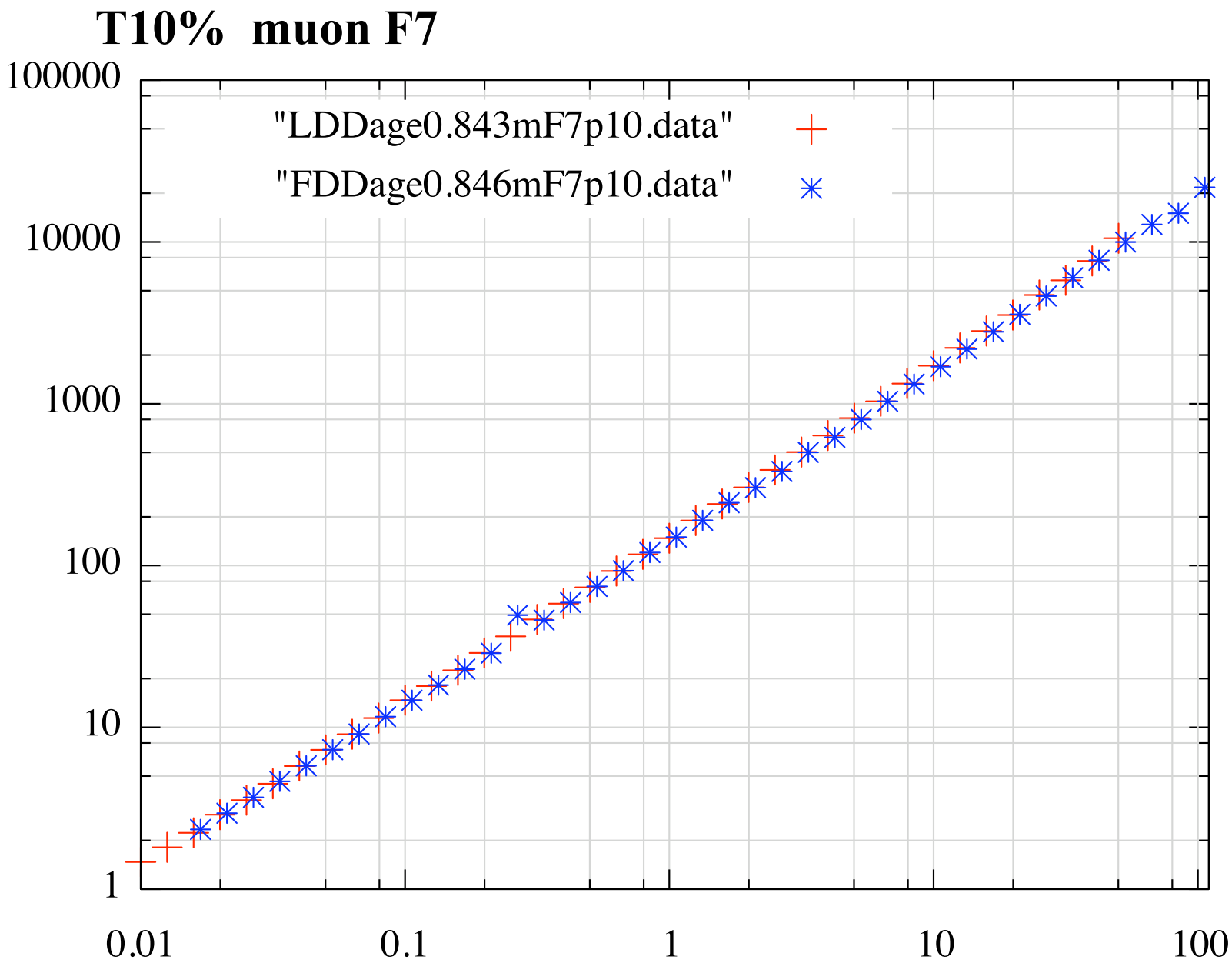
T10 % muon F1

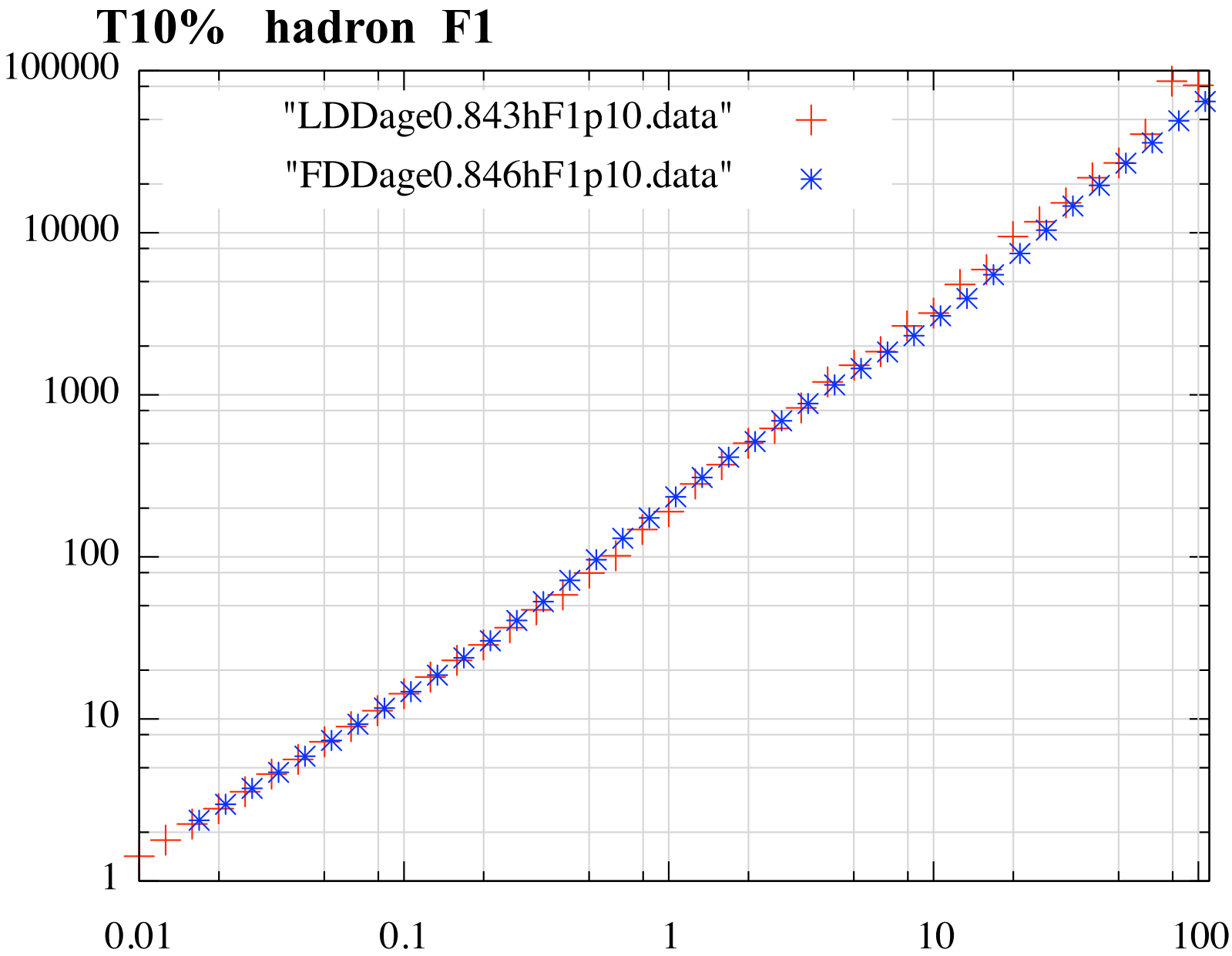

"LDDage0.843mF1p10.data"
"FDDage0.846mF1p10.data"
100000
10000
1000
100
10
1
0.01
0.1
1
10
100

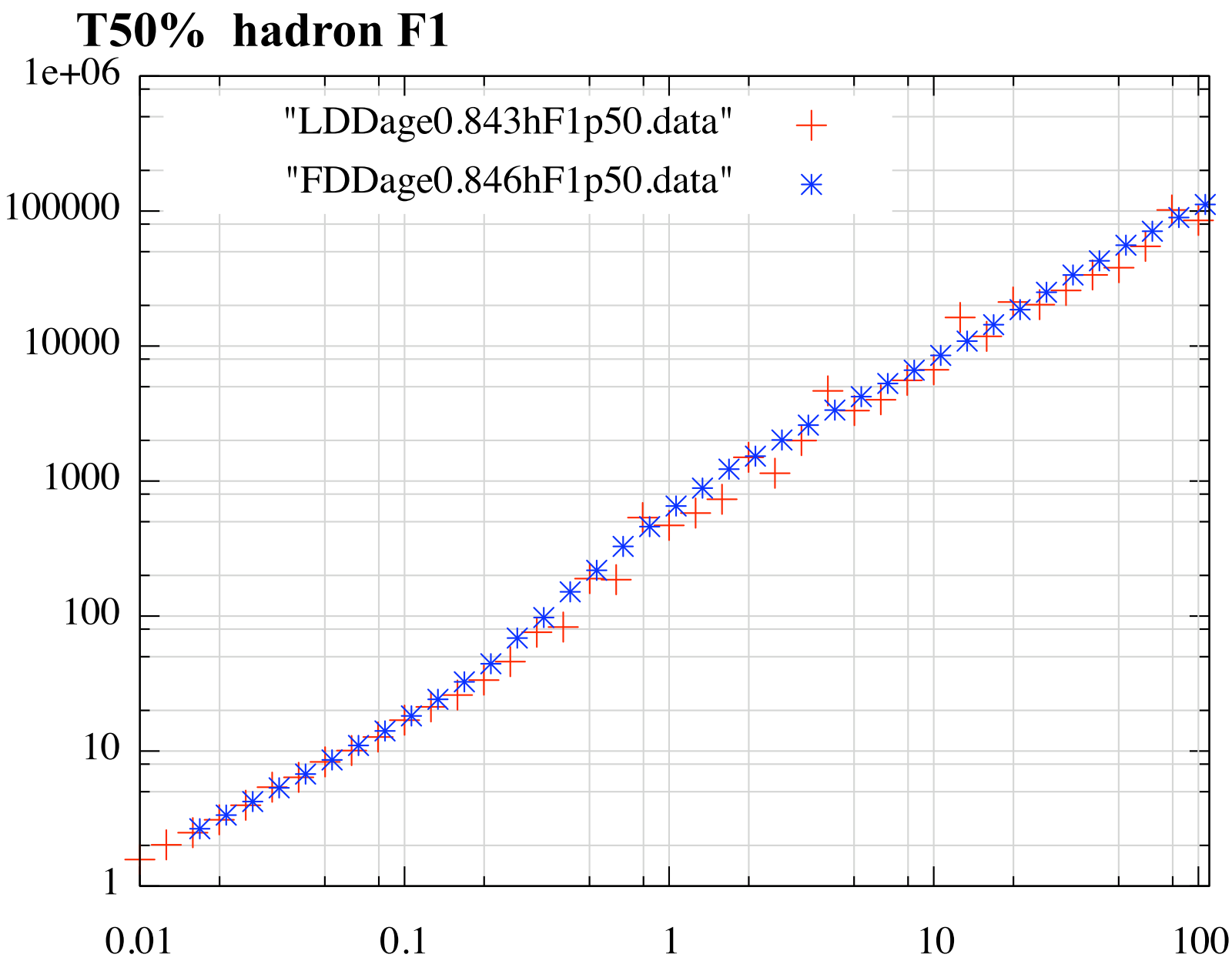

T10% muon F4
"LDDage0.843mF4p10.data"
"FDDage0.846mF4p10.data"
100000
10000
1000
100
10
1
0.01
0.1
1
10
100

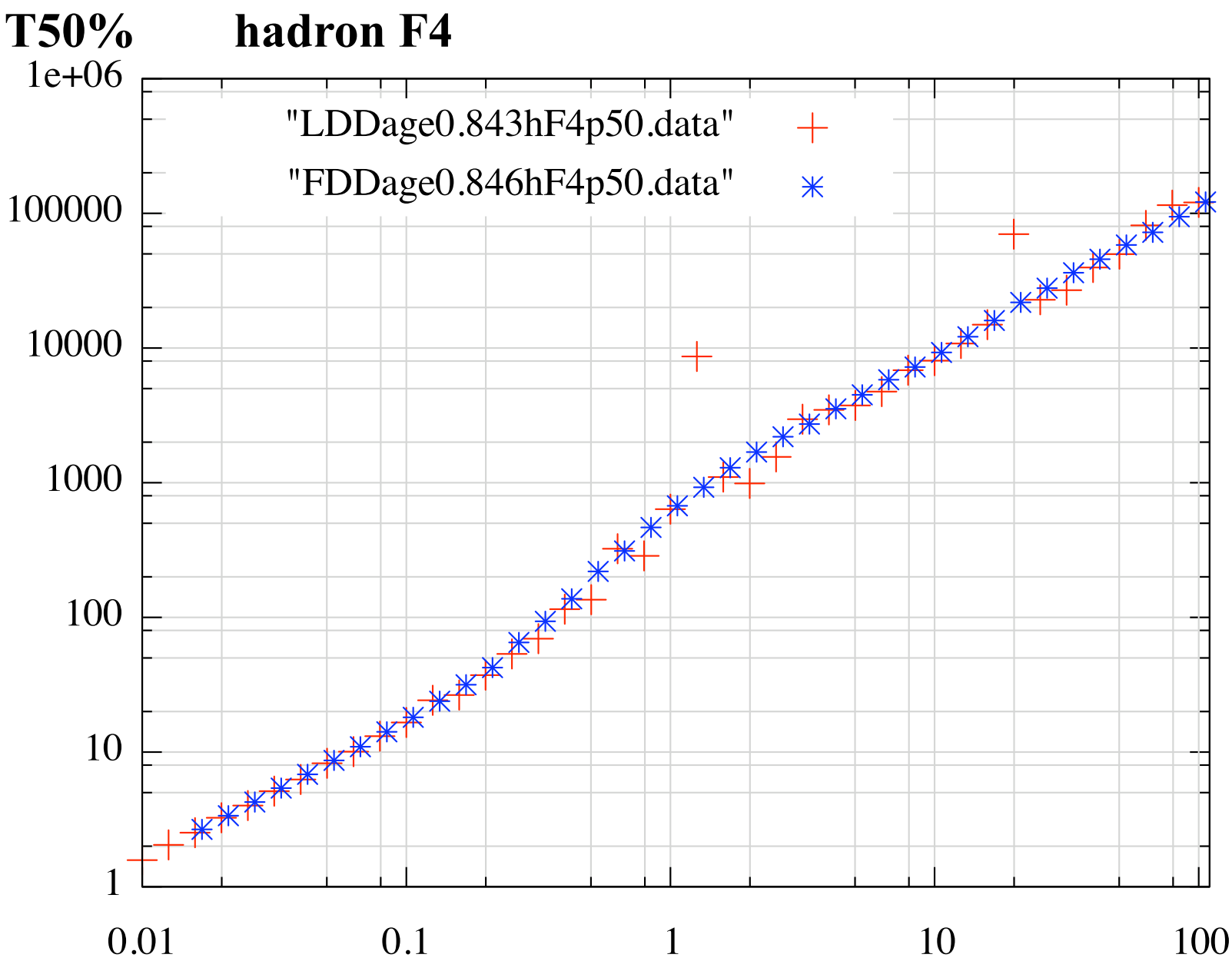

T50% muon F4
"LDDage0.843mF4p50.data"
"FDDage0.846mF4p50.data"
100000
10000
1000
100
10
1
0.01
0.1
1
10
100

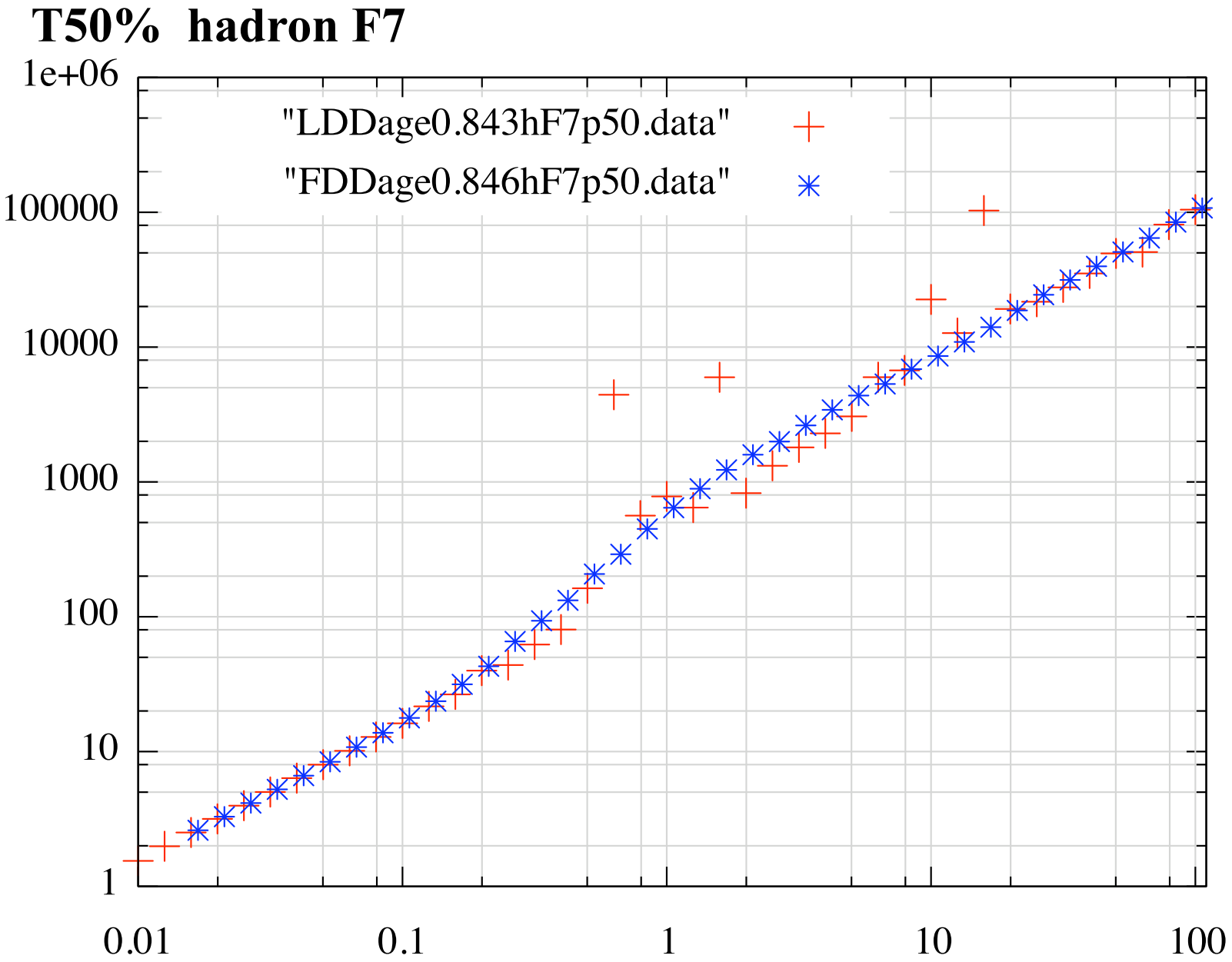

T90% muon F4
"LDDage0.843mF4p90.data"
"FDDage0.846mF4p90.data"
100000
10000
1000
100
10
1
0.01
0.1
1
10
100


T10% muon F7
"LDDage0.843mF7p10.data"
"FDDage0.846mF7p10.data"
100000
10000
1000
100
10
1
0.01
0.1
1
10
100


T10% hadron F1
"LDDage0.843hF1p10.data"
"FDDage0.846hF1p10.data"
100000
10000
1000
100
10
1
0.01
0.1
1
10
100


T50% hadron F1
"LDDage0.843hF1p50.data"
"FDDage0.846hF1p50.data"
1e+06
100000
10000
1000
100
10
1
0.01
0.1
1
10
100


T50%
hadron F4
1e+06
100000
10000
1000
100
10
1
0.01
0.1
1
10
100
"LDDage0.843hF4p50.data"
"FDDage0.846hF4p50.data"


T50% hadron F7
"LDDage0.843hF7p50.data"
"FDDage0.846hF7p50.data"
1e+06
100000
10000
1000
100
10
1
0.01
0.1
1
10
100