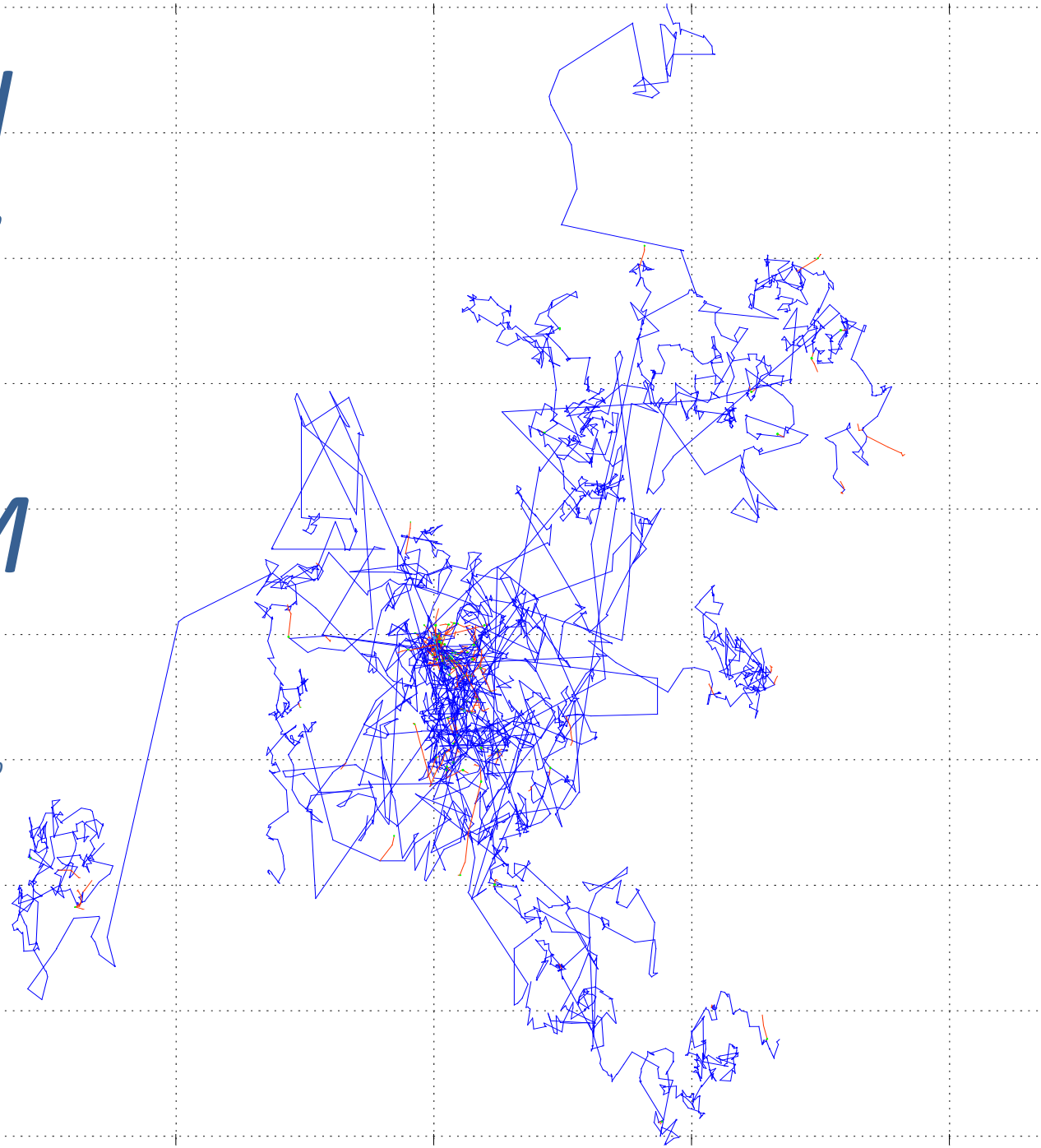
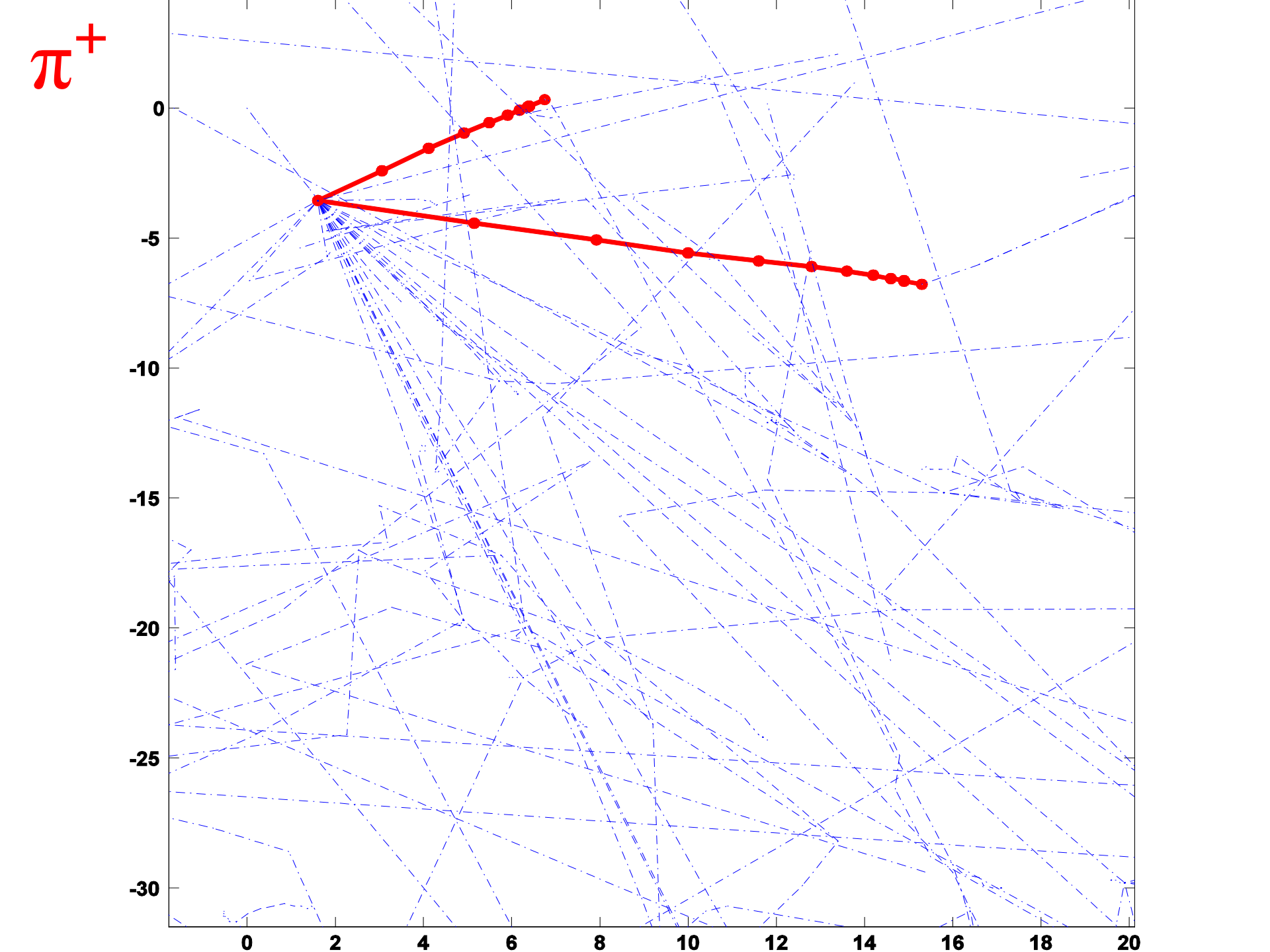
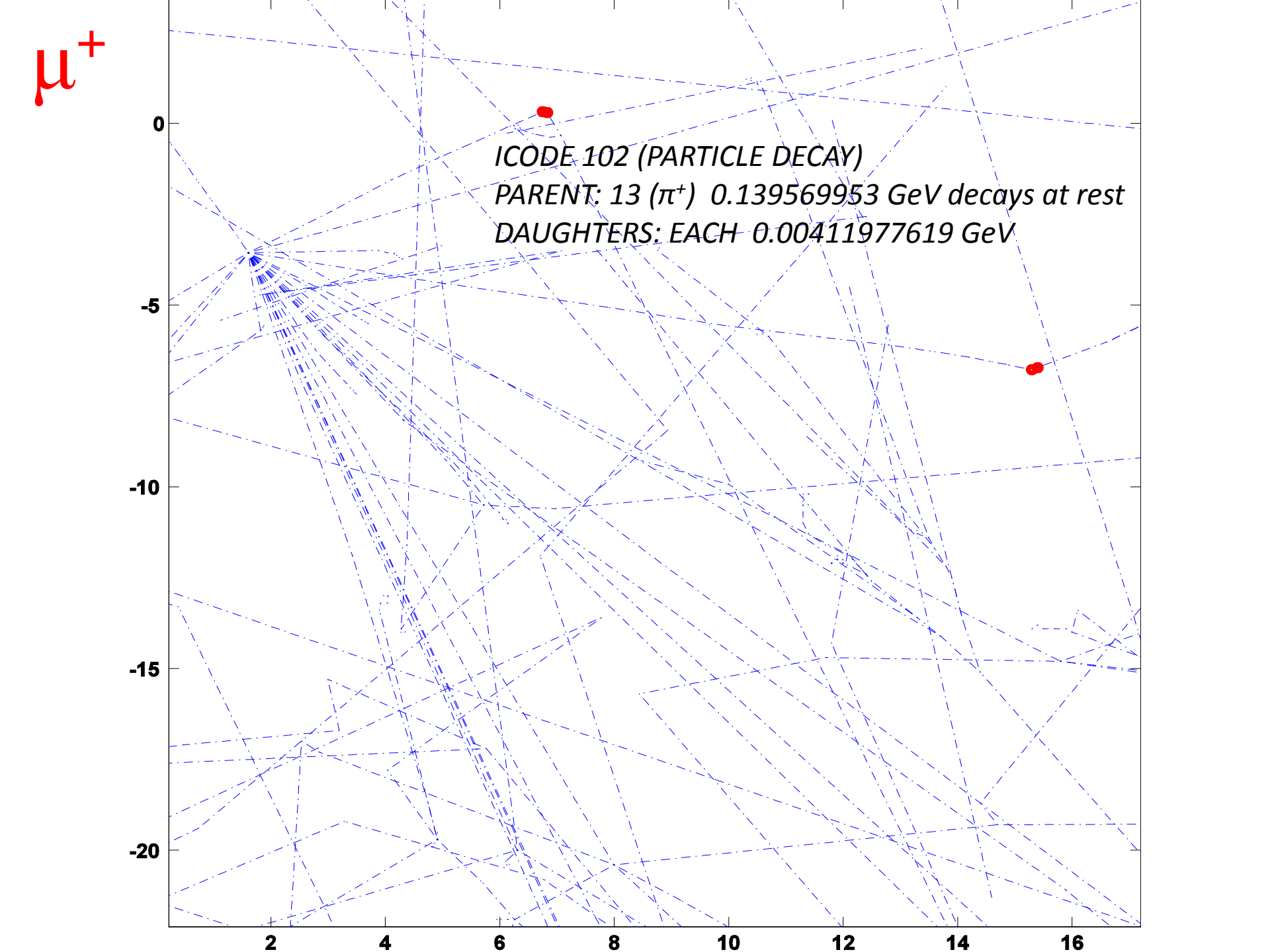
CARBON STORIES IN CALCIUM

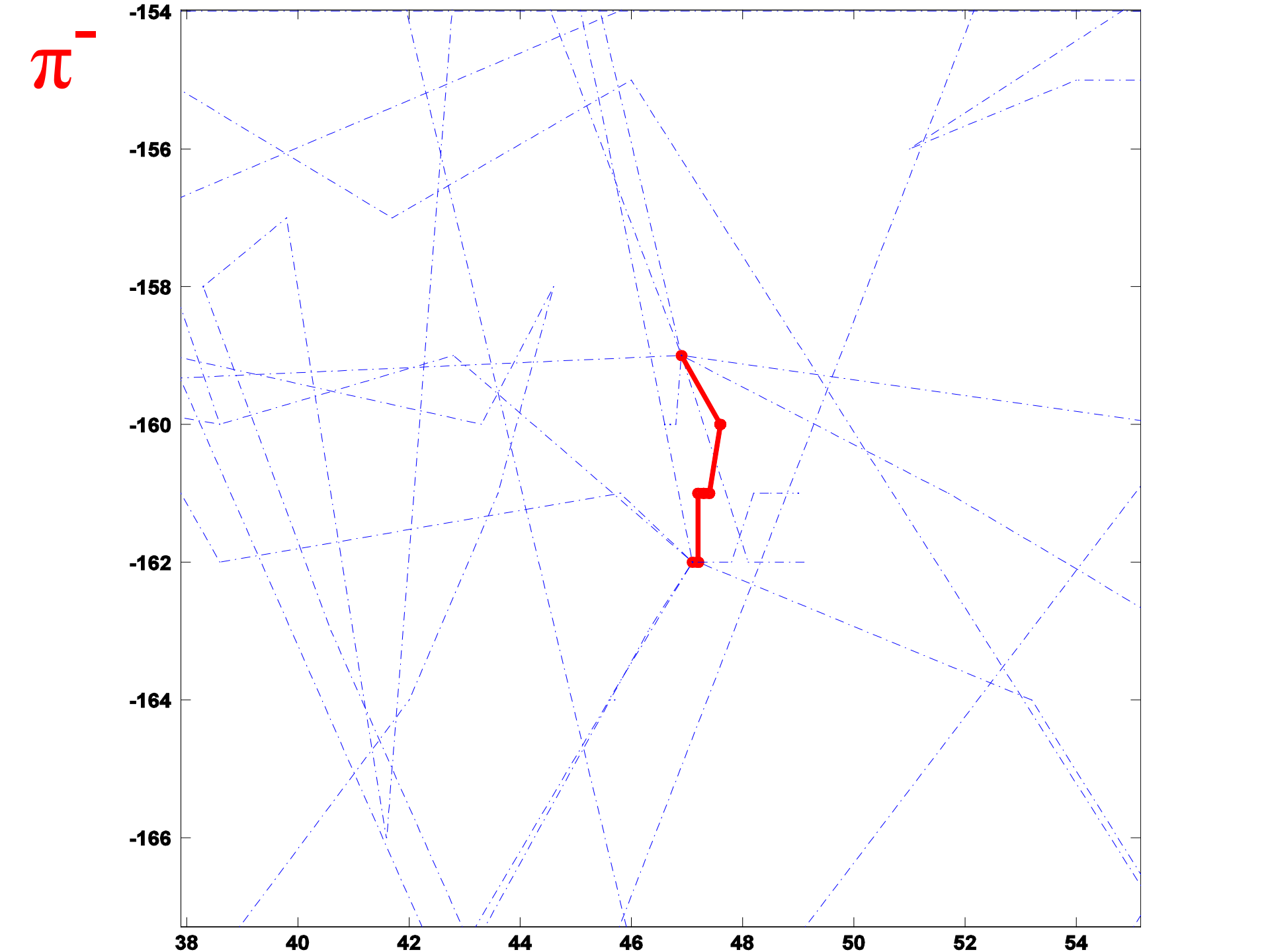
mary.chin@cern.ch

1st FLUKA Advanced Course & Workshop
Ericeira 4-8 Oct 2010

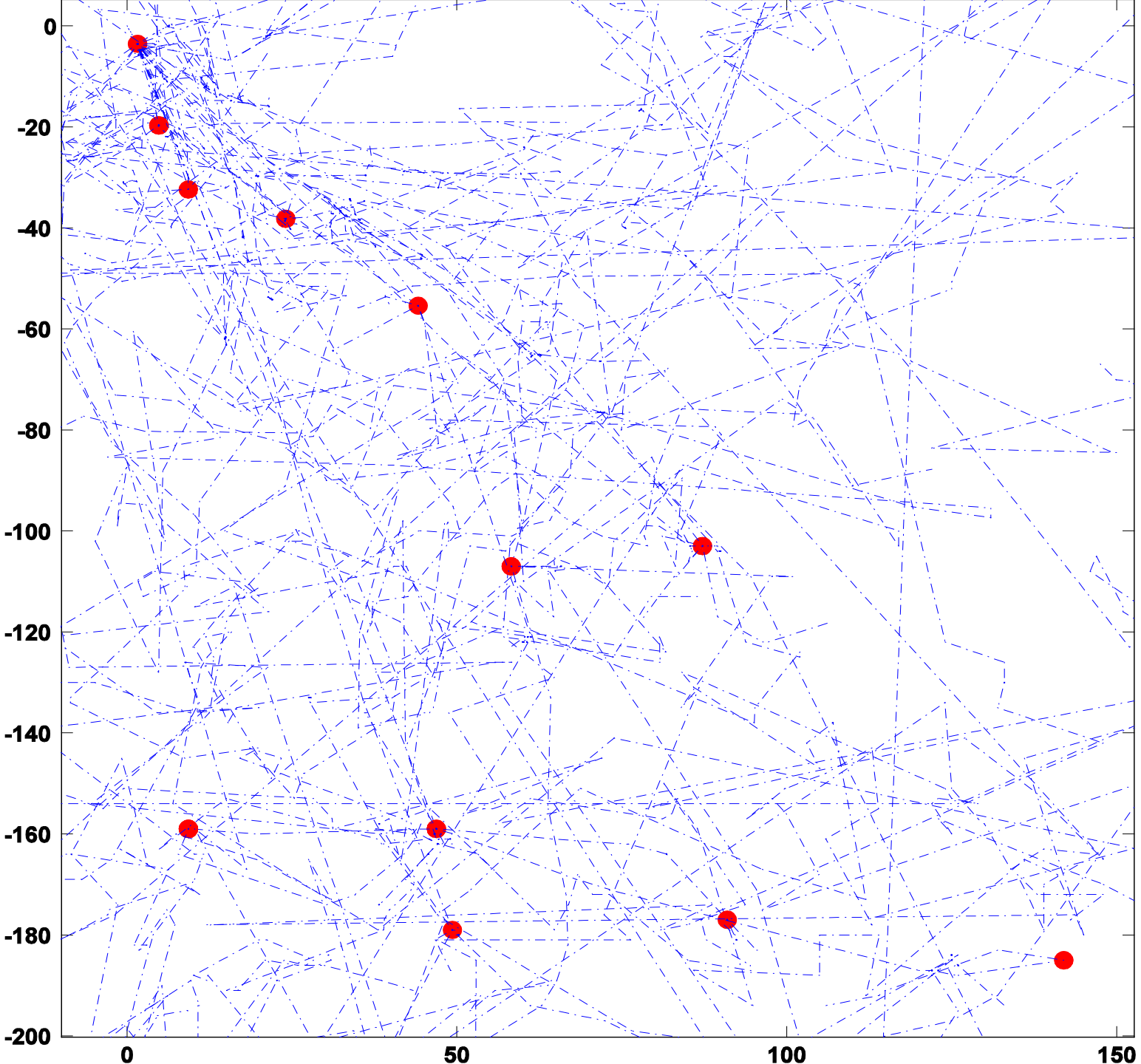


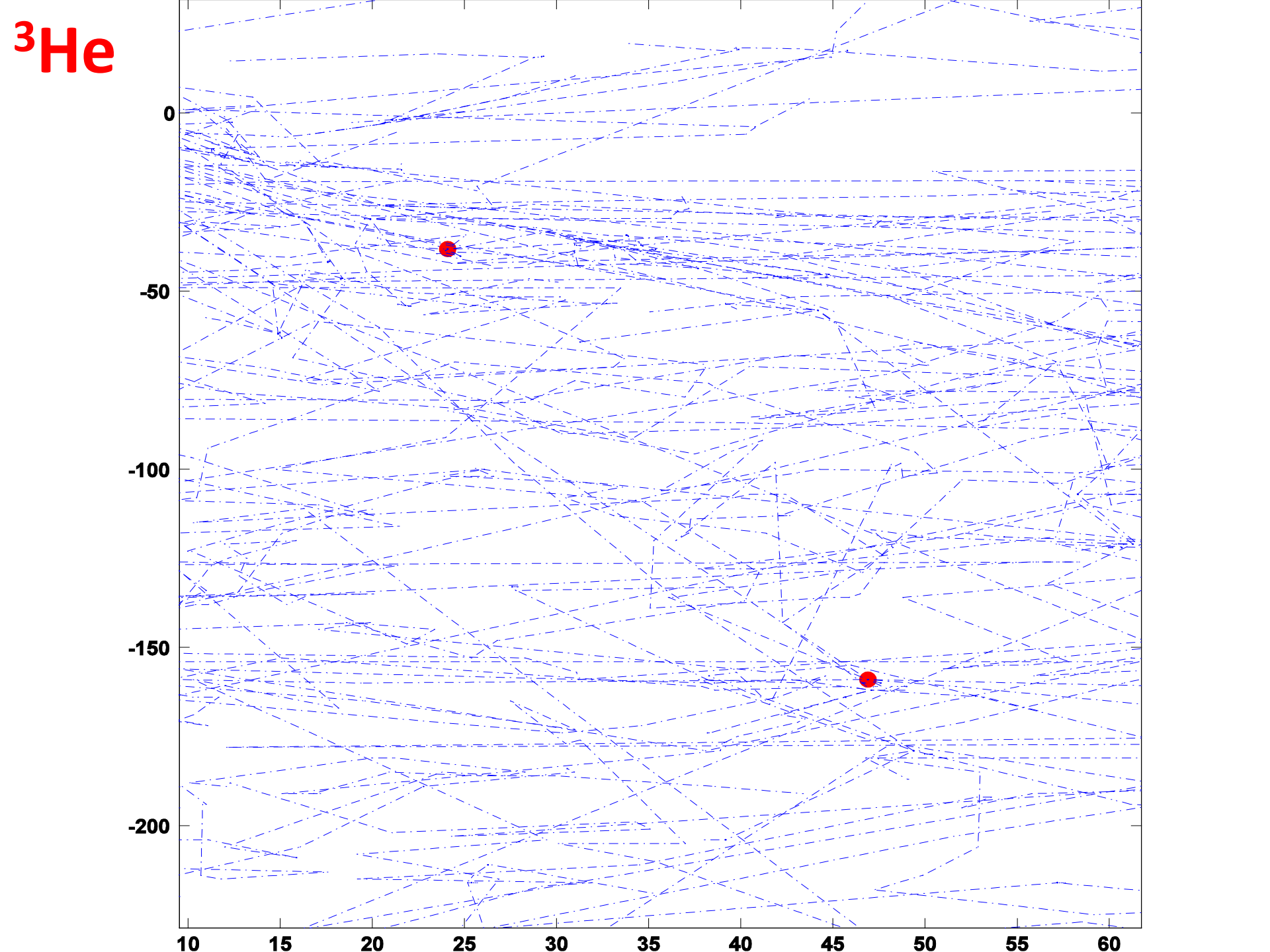

π^+
0
-5
-10
-15
-20
-25
-30
0
2
4
6
8
10
12
14
16
18
20

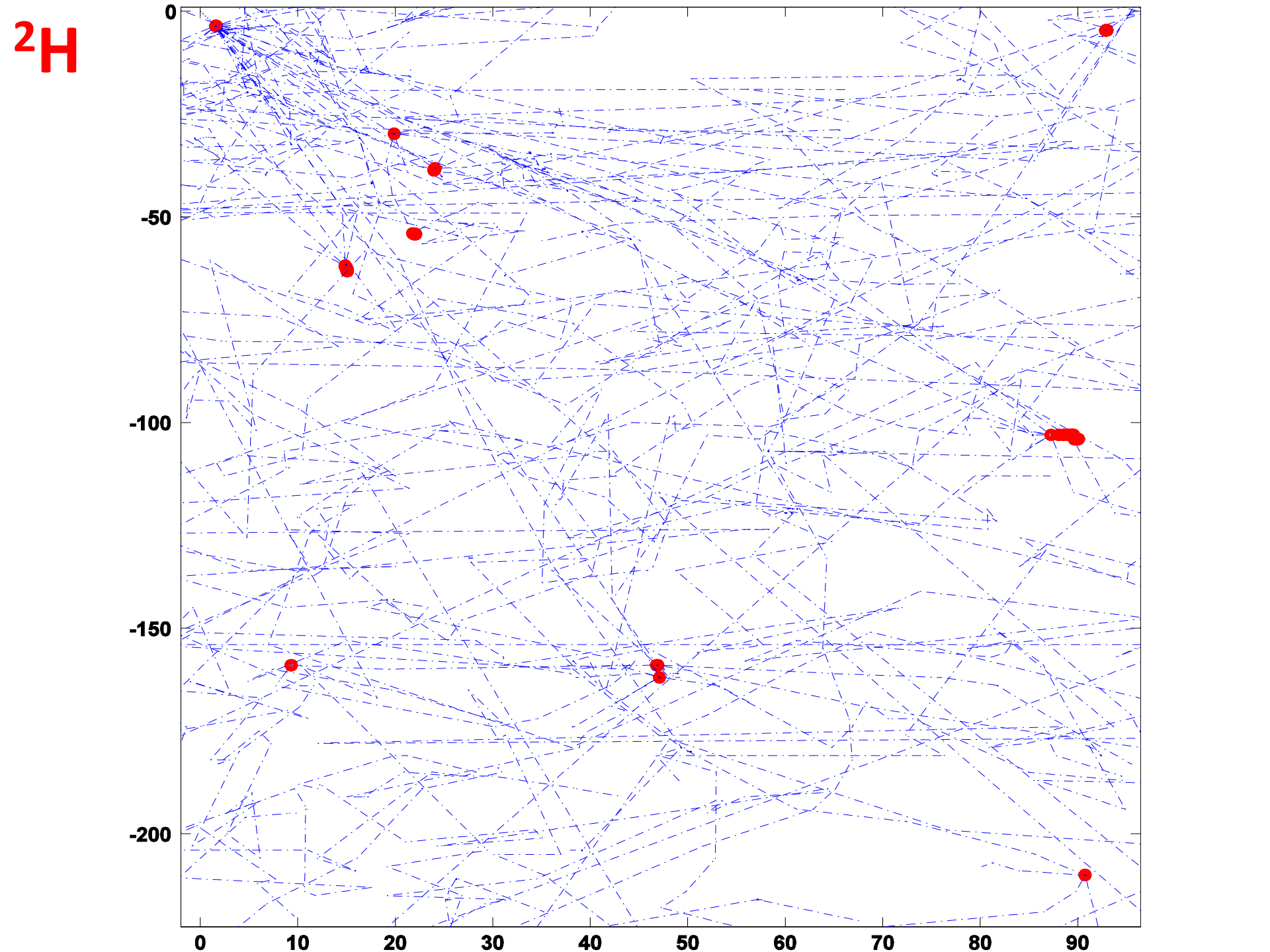

μ+
ICODE 102 (PARTICLE DECAY)
PARENT: 13 (π+) 0.139569953 GeV decays at rest
DAUGHTERS: EACH 0.00411977619 GeV
0
-5
-10
-15
-20
2
4
6
8
10
12
14
16

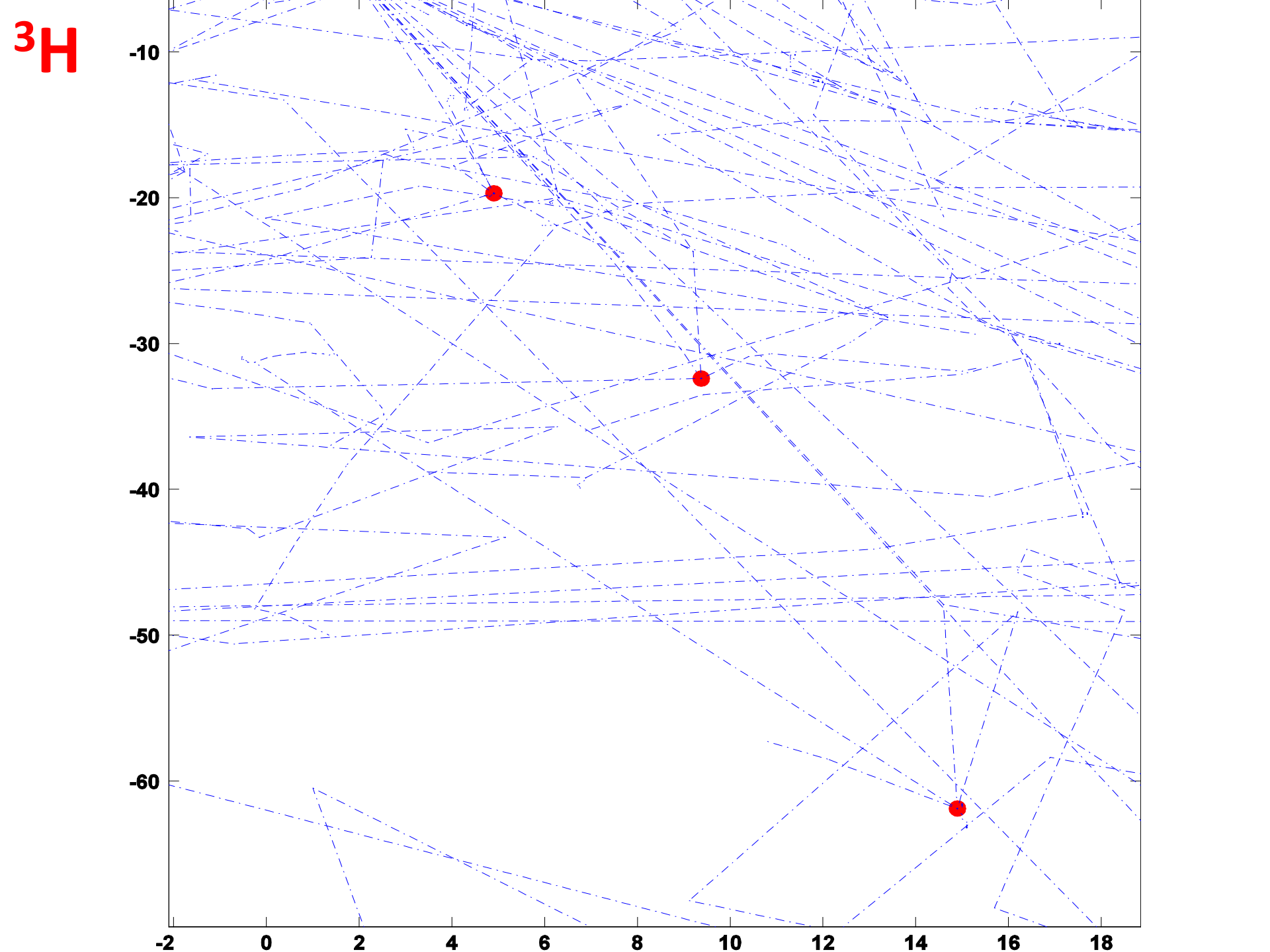

π^-
-154
-156
-158
-160
-162
-164
-166
38
40
42
44
46
48
50
52
54

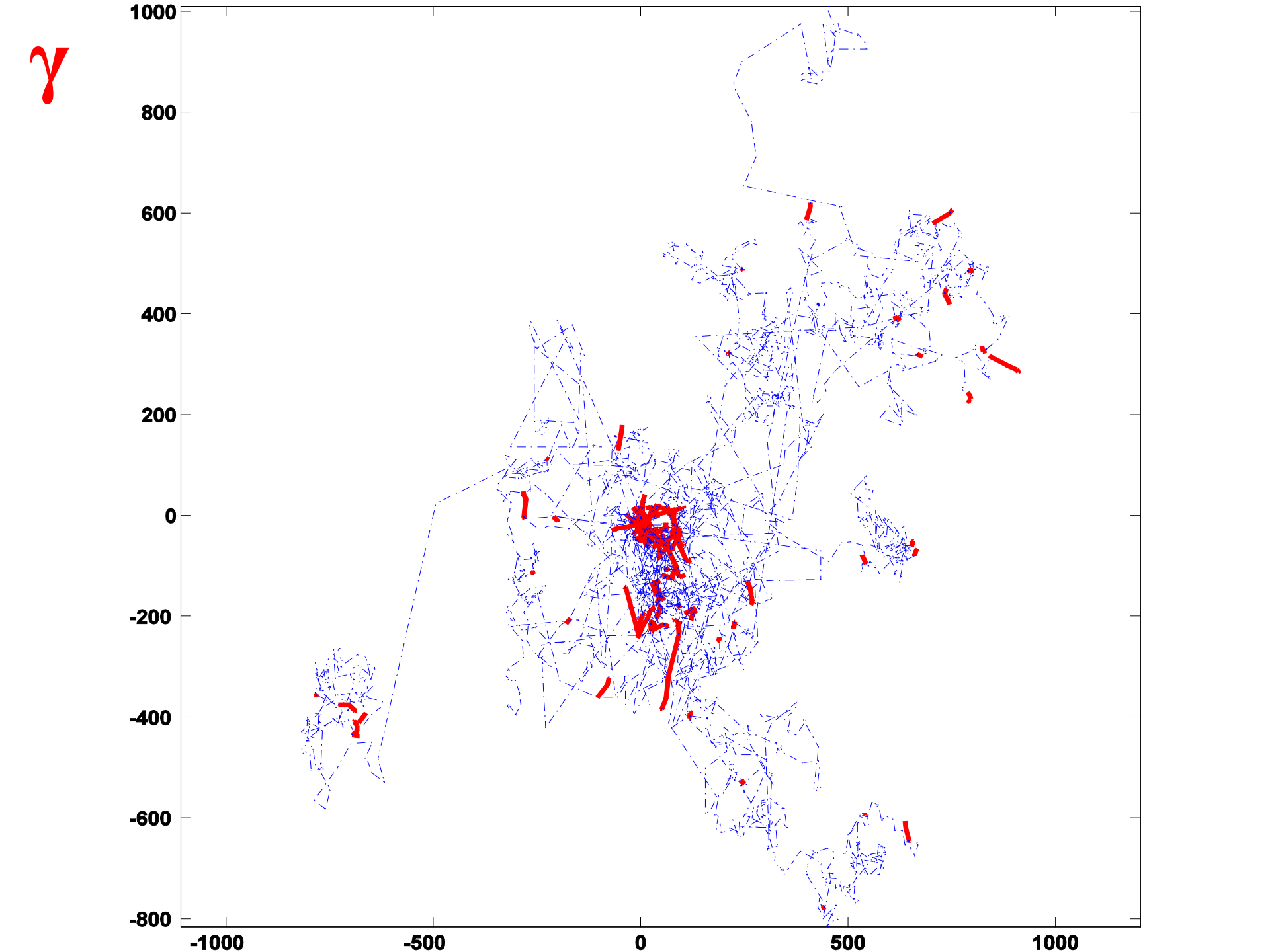
α

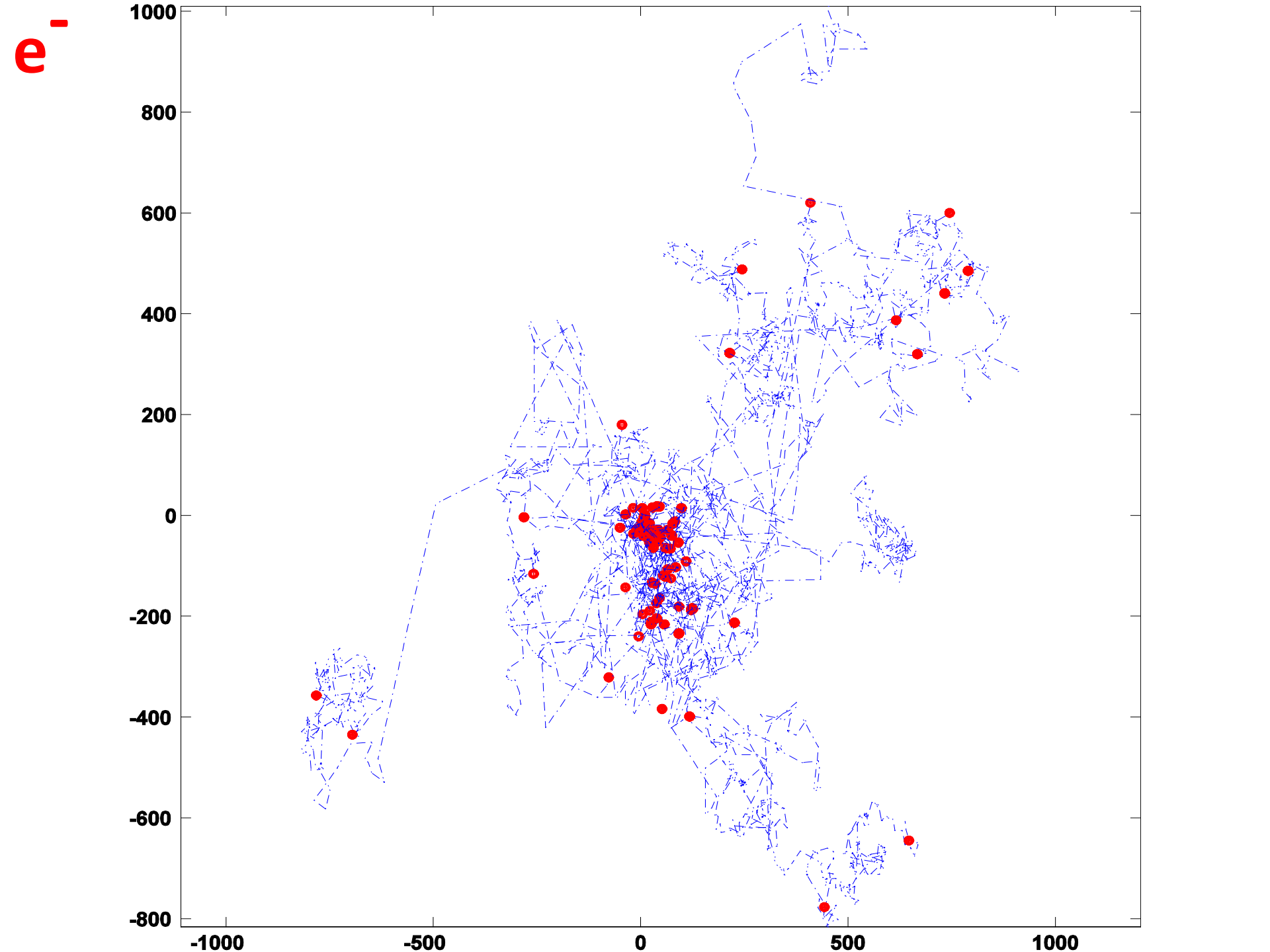


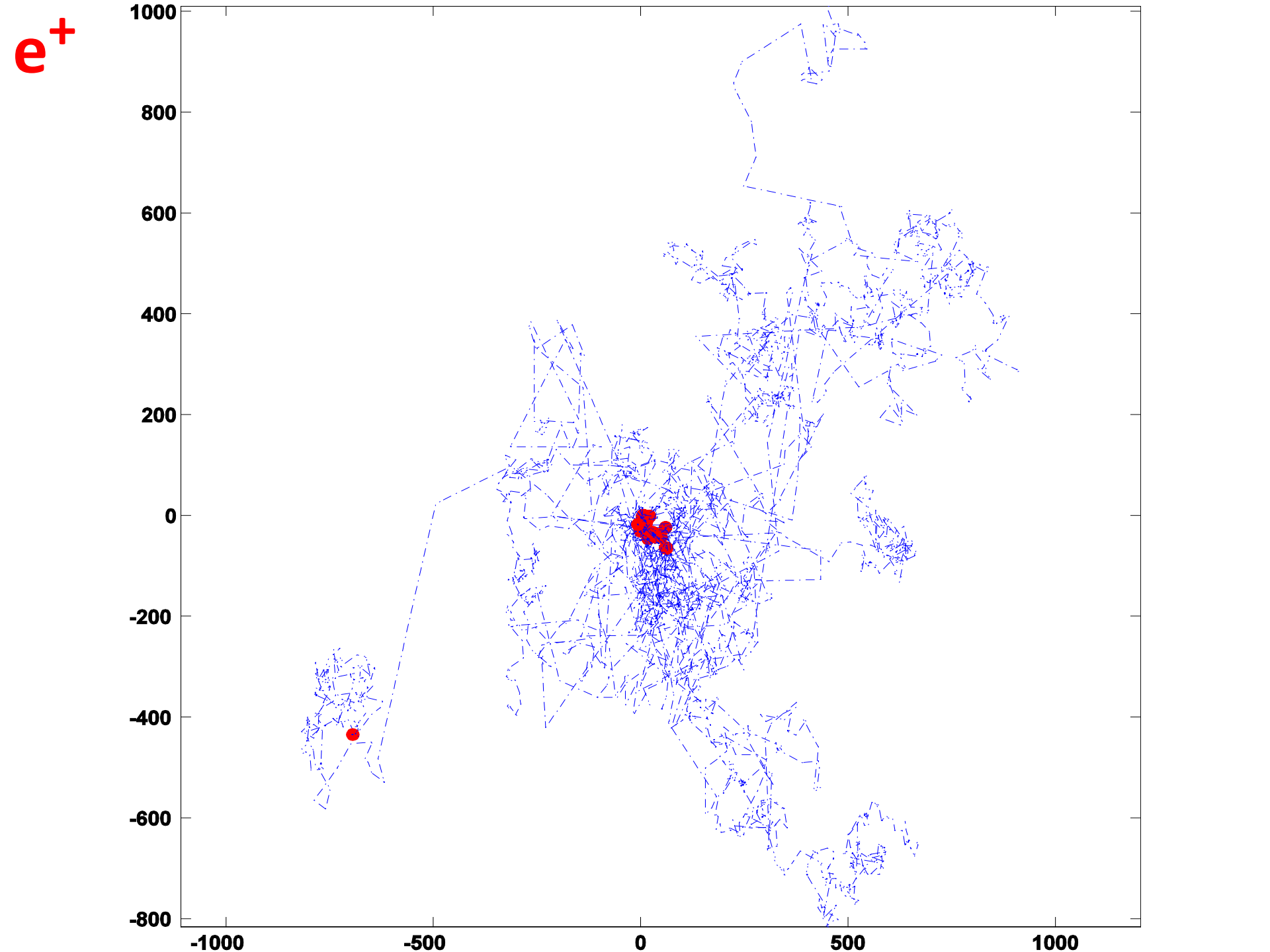

^{3}He
0
-50
-100
-150
-200
10
15
20
25
30
35
40
45
50
55
60

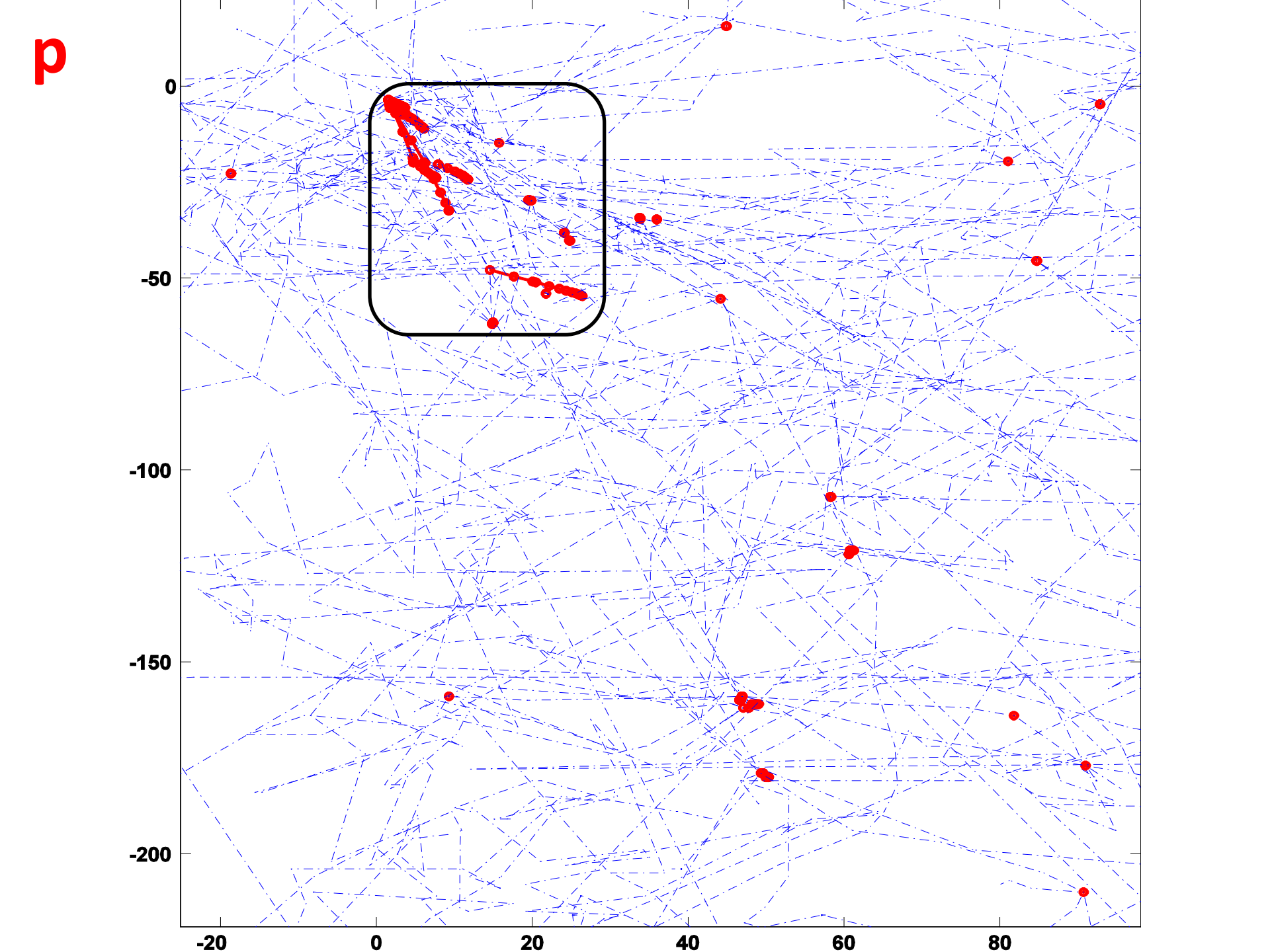

^{2}H
0
-50
-100
-150
-200
0
10
20
30
40
50
60
70
80
90


^{3}H
-10
-20
-30
-40
-50
-60
-2
0
2
4
6
8
10
12
14
16
18

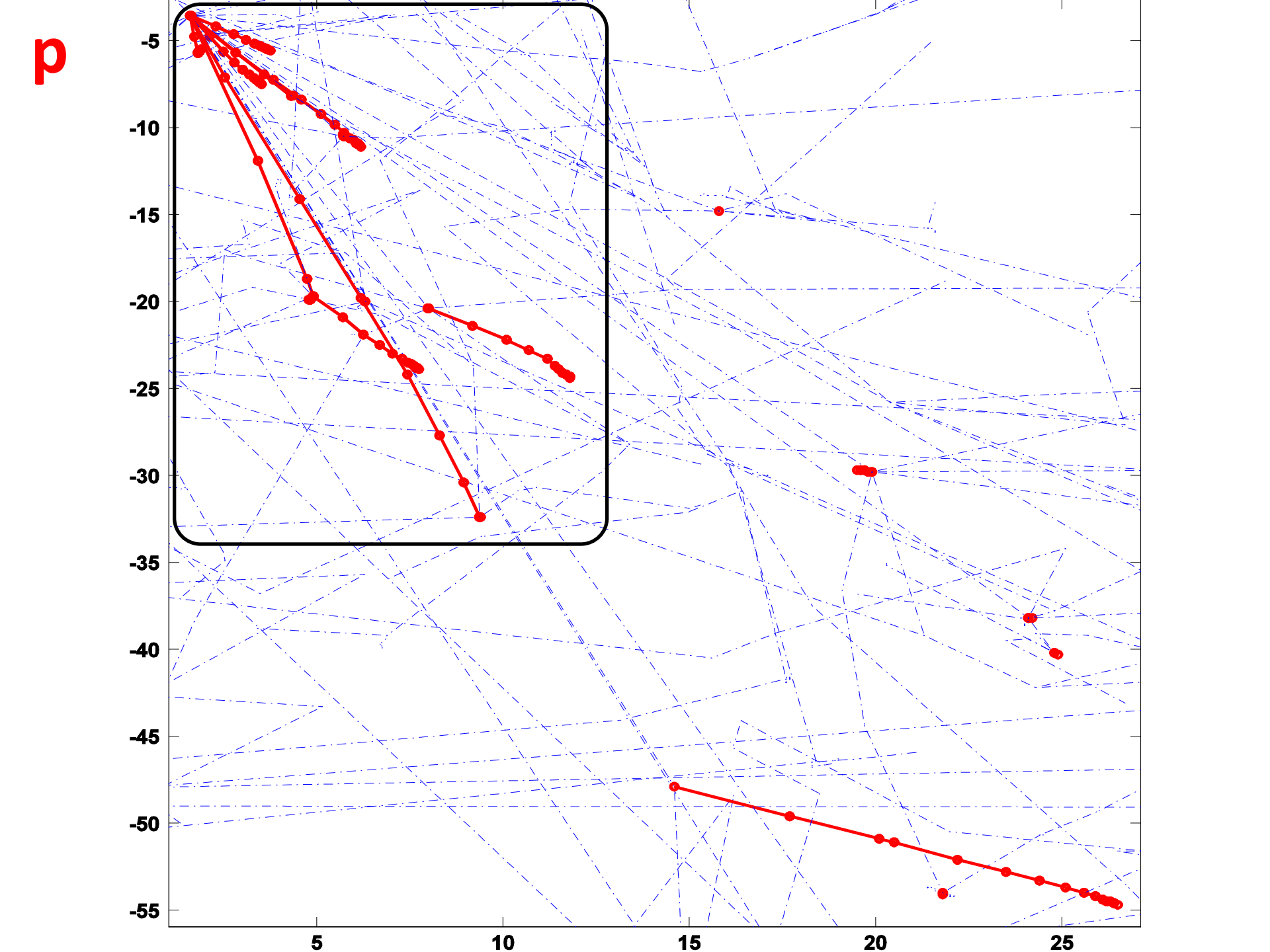

γ
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
-500
0
500
1000

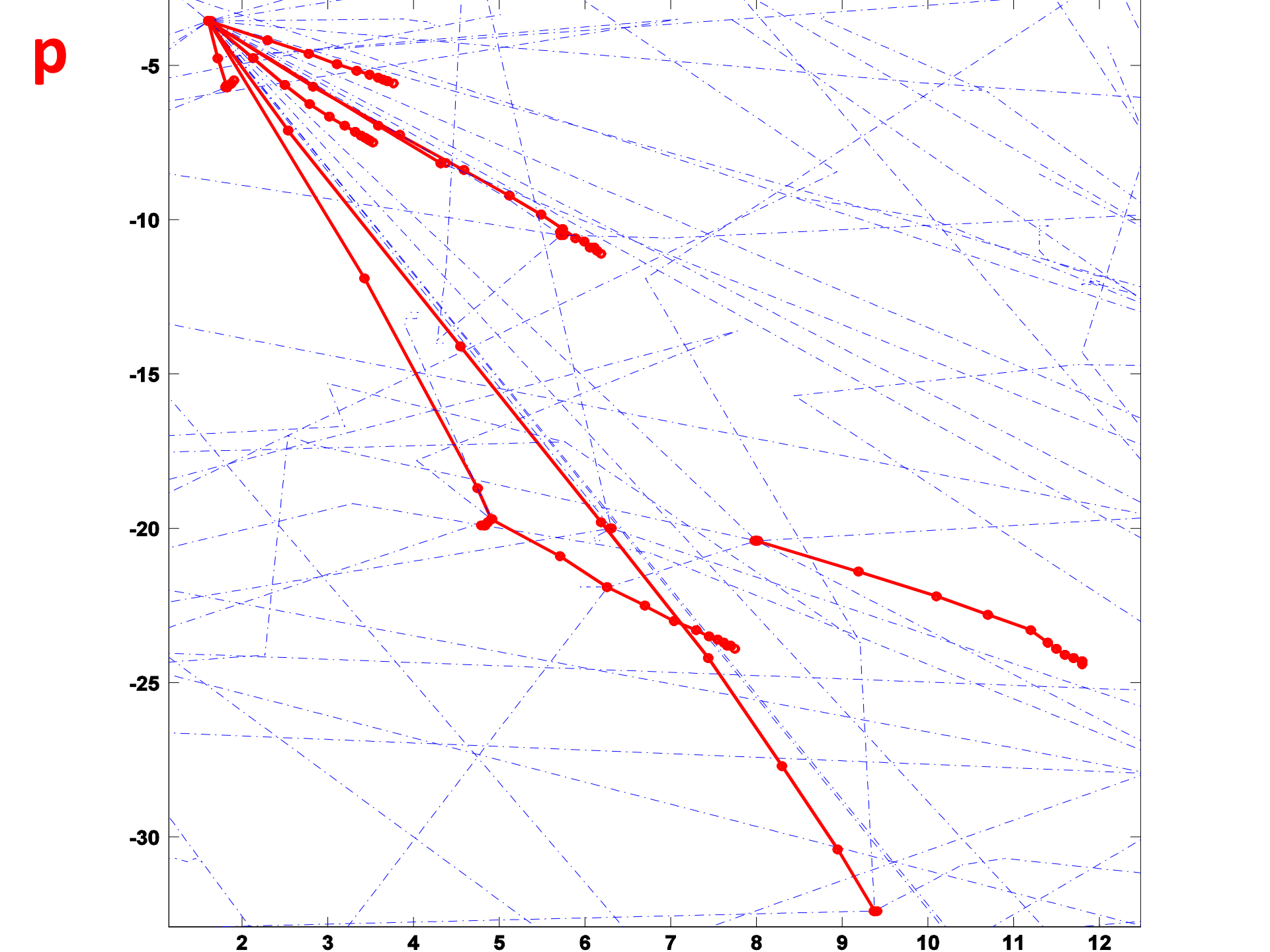

e-
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
-500
0
500
1000


e+
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
-500
0
500
1000


p
0
-50
-100
-150
-200
-20
0
20
40
60
80

p




p
-5
-10
-15
-20
-25
-30
2
3
4
5
6
7
8
9
10
11
12

.out

Fluka incident beam properties:

Beam particle: HEAVYION Id: -2 (Fluka) 9999 (PDG) Charge: 6 Baryon n.: 12

Mass: 11.17 (GeV/c^2) Mean life: 1.0000E+18 (s) Weight: 1.000

Average beam momentum : 11.415723 (GeV/c)

Average beam kinetic energy: 4.800000 (GeV)

Momentum deviation at FWHM (rectangular): 0.0000000 (GeV/c)

Beam hit position : 0.00000000 0.00000000 0.00000000 cm

Beam direction cosines: 0.00000000 0.00000000 1.00000000

Beam spot FWHM X-width (Rectangular): 0.0000 cm

Beam spot FWHM Y-width (Rectangular): 0.0000 cm

Beam FWHM angular divergence (Isotropic): ********* (mrad)

(Spatial distribution, polarization, and angular direction and distribution are given in the beam frame of reference)

Beam reference frame (world coordinates):

Beam X axis: 1.00000000 0.00000000 0.00000000

Beam Y axis: 0.00000000 1.00000000 0.00000000

Beam Z axis: 0.00000000 0.00000000 1.00000000

The nominal beam position belongs to region: 3(RSEA), lattice cell: 0( )

Heavy ion beam requested, properties:

Mass number of the projectile: 12

Charge number of the projectile: 6

Isomer number of the projectile: 0

Laboratory momentum of the projectile : 0.9513 (GeV/c/amu)

Laboratory kin. energy of the projectile: 0.4000 (GeV/amu)

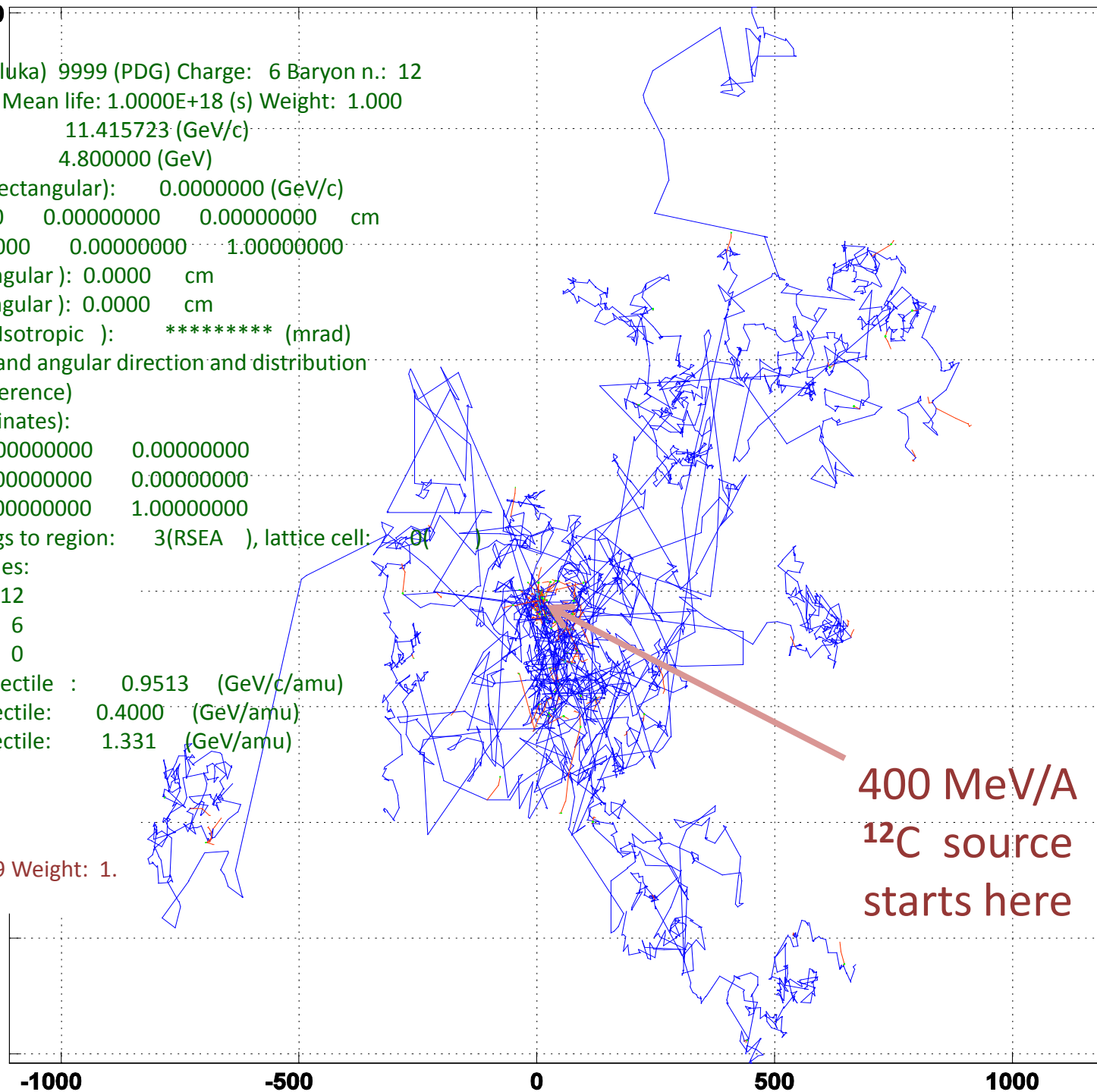
Laboratory tot. energy of the projectile: 1.331 (GeV/amu)

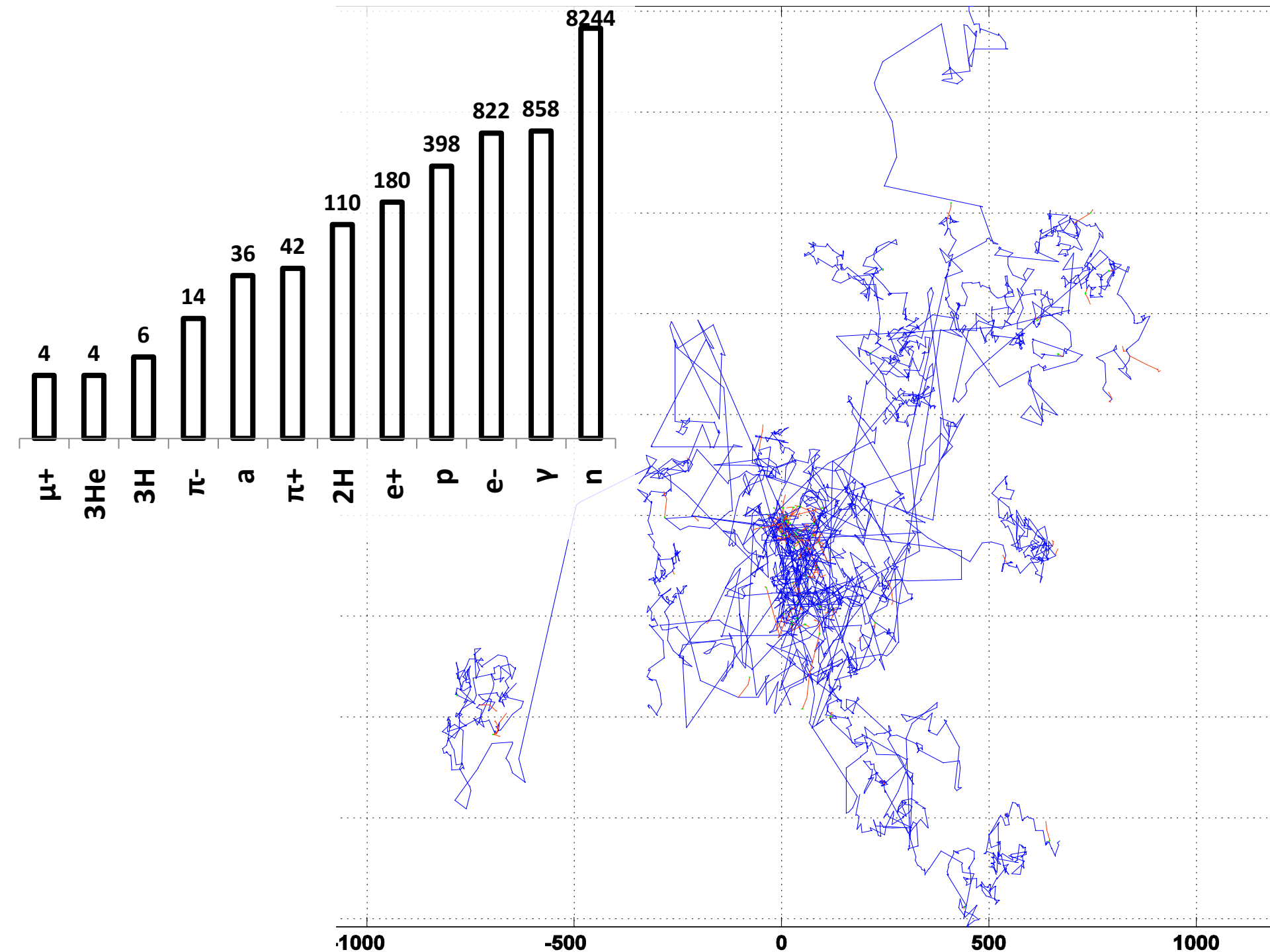
COLLISION TAPE

Source particle(s), n. of: 1

Part.id.: -30 Tot.en.: 15.9748669 Weight: 1.

Position : 0. 0. 0.




8244
858
822
398
180
110
42
36
14
6
4
4
μ+
3He
3H
π-
a
π+
2H
e+
p
e-
γ
n
-1000
-500
0
500
1000

SO MANY NEUTRONS
where do they come from?

count	icode	parent	siblings
13	101	$^{12}C + ^{40}Ca$	$^{24}_{12}Mg + ^{4}_{2}He + ^{2}_{1}H + 9^{1}_{1}p + 13n + 2\pi^{+} + 2\gamma$
5	101	p	n+p n+3p+3γ n+3p 2n+2p+γ
3	101	π-	p+3n+4γ
103	101	 n	2 to 12 siblings many x_1n+x_2p+x_3γ 2p+4n+2γ+^{2}H 3n+3p+2γ+π $^-$+^{2}H+^{3}He+2α
3998	100, 101 or 300	n	s o l o

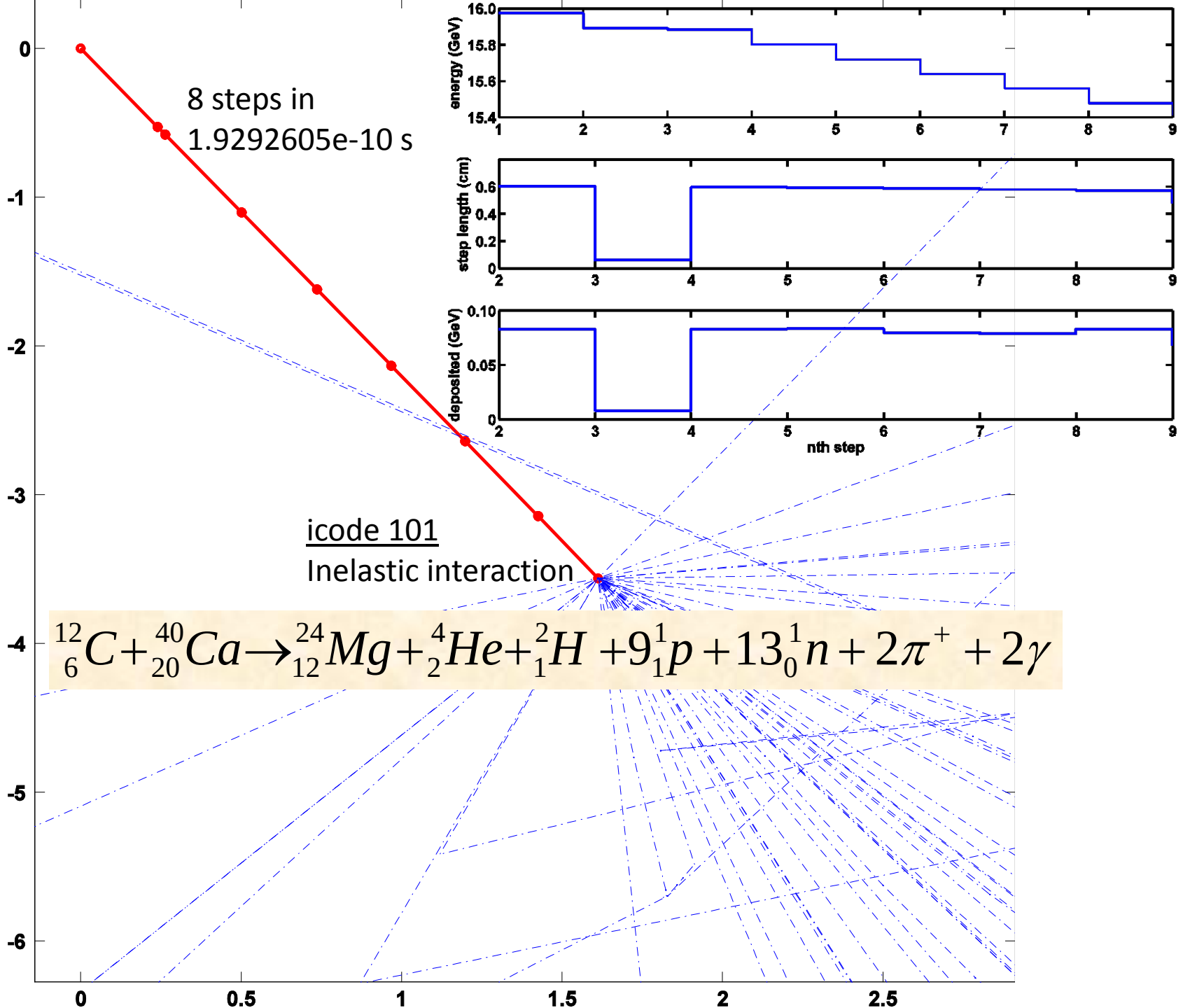
instead of the usual Np, Kpart, Tki

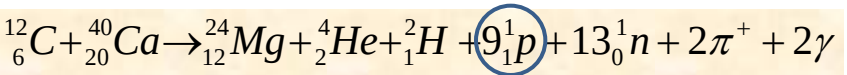
```
IF (ICODE.EQ.101 .AND. JTRACK.EQ.-2 .AND. npheav.GT.0) THEN
      DO I=1,npheav
         WRITE(IODRAW) NCASE,SNGL(ETRACK),SNGL(PTRACK),
     &          npheav, kheavy(I),
     &          ibheav(kheavy(I)), icheav(kheavy(I)),
     &          SNGL(tkheav(I)), SNGL(pheavy(I))
      END DO
END IF
```

count	icode	parent	siblings
13	101	^{12}C +^{40}Ca	$^{24}_{12}Mg+^{4}_{2}He+^{2}_{1}H+9^{1}_{1}p+13n+2\pi^{+}+2\gamma$
5	101	p	n+p n+3p+3γ n+3p 2n+2p+γ
3	101	π-	p+3n+4γ
103	101	 n	2 to 9 siblings many x_1n+x_2p+x_3γ 2p+4n+2γ+^{2}H 3n+3p+2γ+π $^{-}$+^{2}H
3998	100, 101 or 300	n	s o l o

→ HEAVY ION INTERACTION

^{12}C

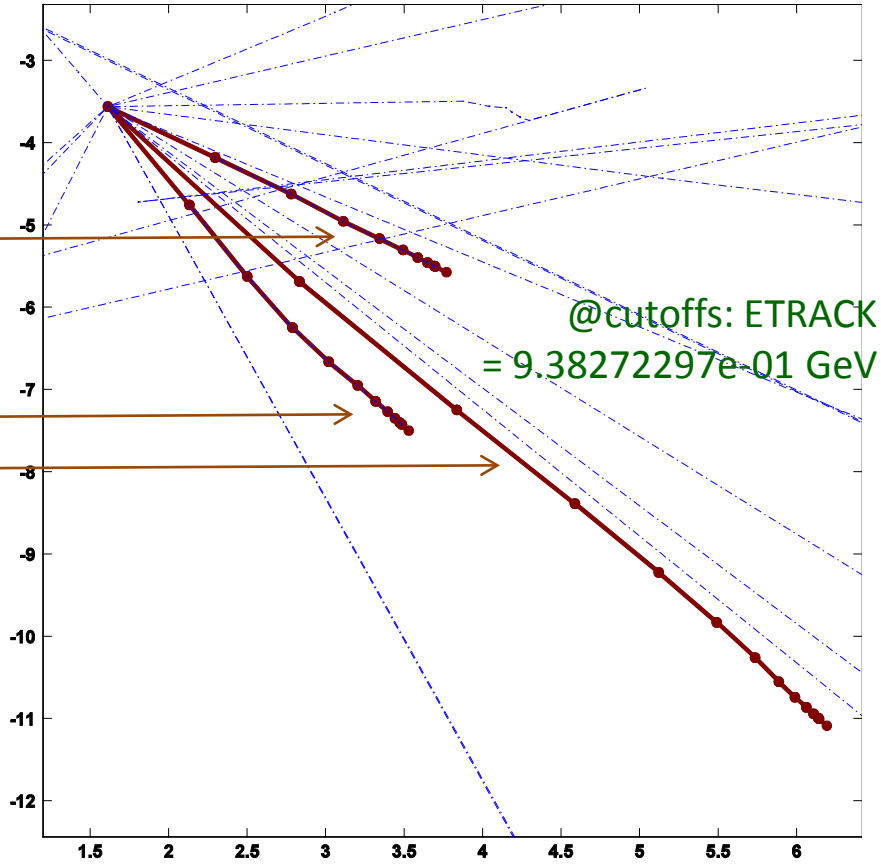

8 steps in
1.9292605e-10 s
energy (GeV)
step length (cm)
deposited (GeV)
nth step
icode 101
Inelastic interaction
$^{12}_{6}C+^{40}_{20}Ca\rightarrow^{24}_{12}Mg+^{4}_{2}He+^{2}_{1}H+9^{1}_{1}p+13^{1}_{0}n+2\pi^{+}+2\gamma$


$^{12}_{6}C + ^{40}_{20}Ca \rightarrow ^{24}_{12}Mg + ^{4}_{2}He + ^{2}_{1}H + 9^{1}_{1}p + 13^{1}_{0}n + 2\pi^{+} + 2\gamma$

PROTONS

Tki (GeV)	next step	icode
2.85969377e-01	(p,2n+2p+γ)	101
7.94009790e-02	(p,n+3p)	101
6.70373663e-02	10 steps to cutoff	
3.00997659e-03	1 step to cutoff	
2.87470937e-01	(p,n+3p+3γ)	101
1.83140948e-01	(p,np)	101
9.14871842e-02	11 steps to cutoff	
1.23939060e-01	13 steps to cutoff	
5.24589885e-03	1 step to cutoff	

CUTOFF (GeV)
1.00000000e-02



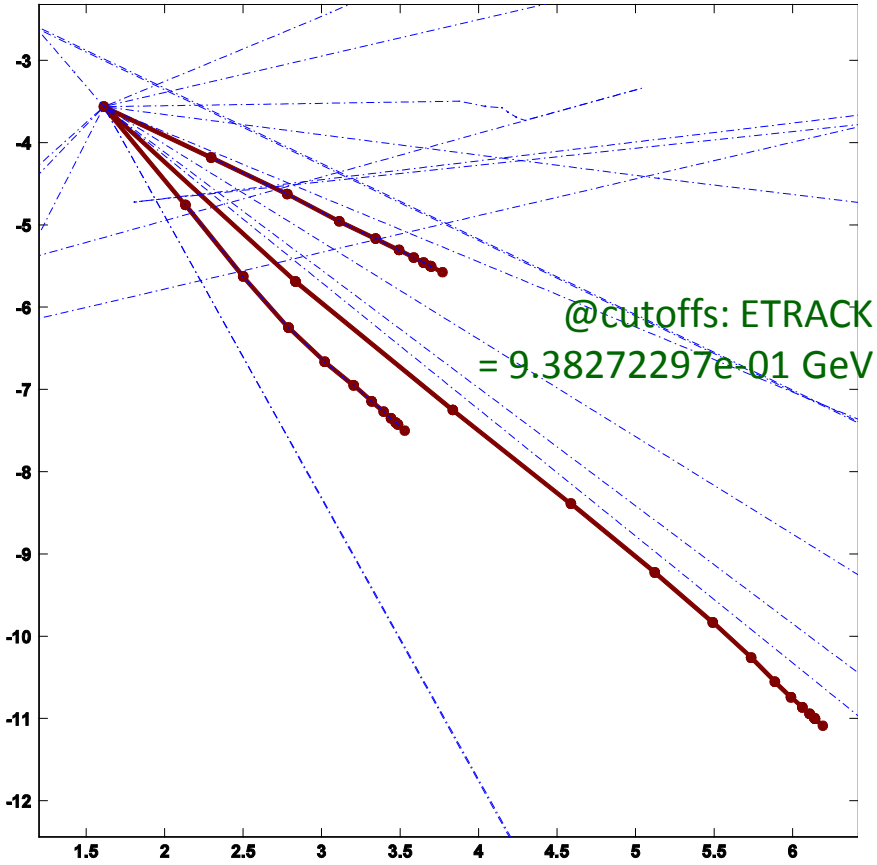
$$^{12}_{6}C + ^{40}_{20}Ca \rightarrow ^{24}_{12}Mg + ^{4}_{2}He + ^{2}_{1}H + 9^{1}_{1}p + 13^{1}_{0}n + 2\pi^{+} + 2\gamma$$

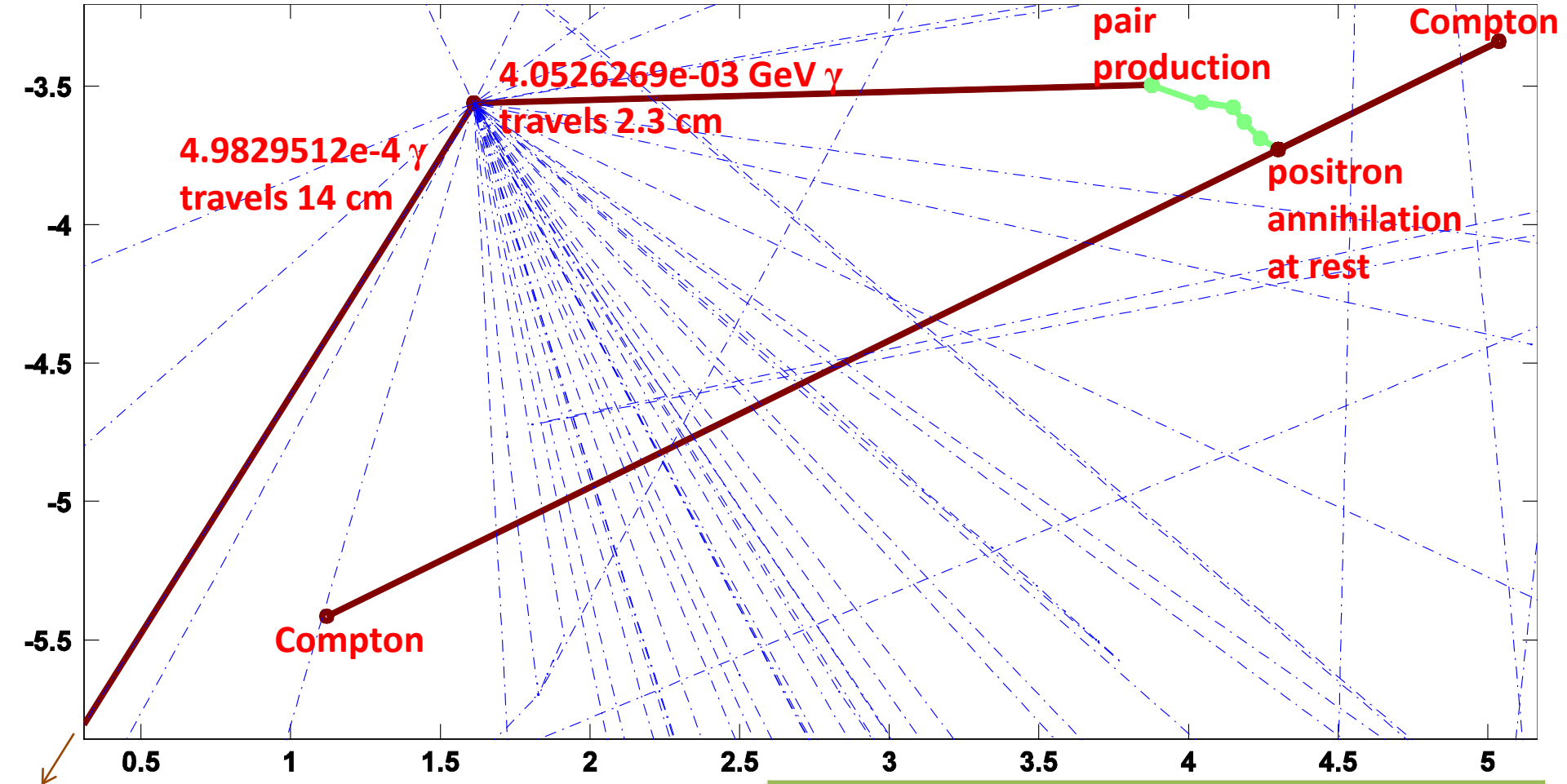
2nd generation of protons

Tki (GeV)	fate
6.08318811e-03	1 step to cutoff
2.59359460e-03	1 step to cutoff
1.59814935e-02	4 steps to cutoff
3.70376068e-03	1 step to cutoff
1.80191698e-03	1 step to cutoff
2.15159506e-02	4 steps to cutoff
1.03988886e-01	6 steps to cutoff
3.61582404e-03	1 step to cutoff
1.02260048e-02	2 steps to cutoff

Tki (GeV)	next step	icode
2.85969377e-01	(p,2n+2p+γ)	101
7.94009790e-02	(p,n+3p)	101
6.70373663e-02	10 steps to cutoff	
3.00997659e-03	1 step to cutoff	
2.87470937e-01	(p,n+3p+3γ)	101
1.83140948e-01	(p,np)	101
9.14871842e-02	11 steps to cutoff	
1.23939060e-01	13 steps to cutoff	
5.24589885e-03	1 step to cutoff	

CUTOFF (GeV)
1.00000000e-02

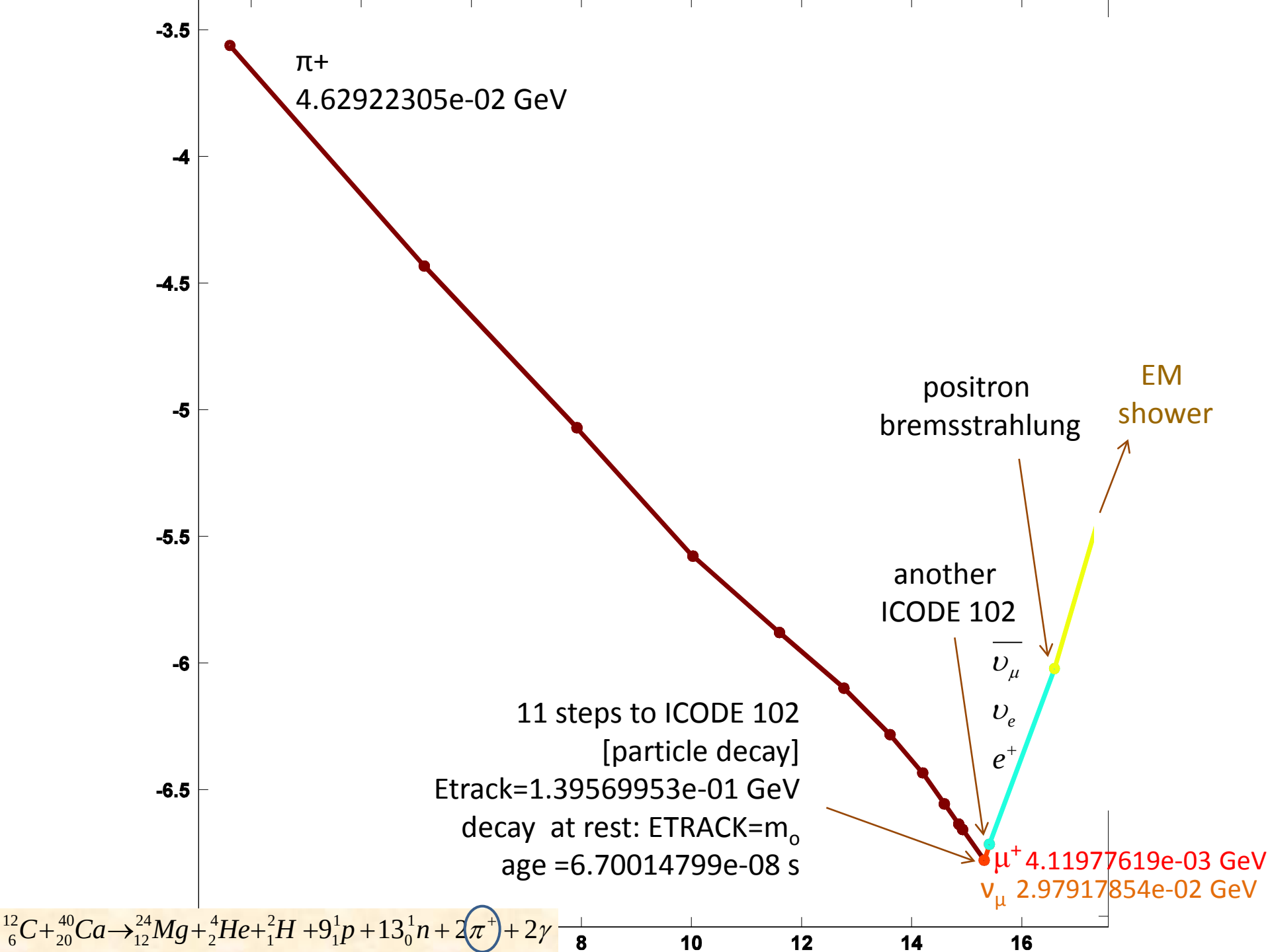


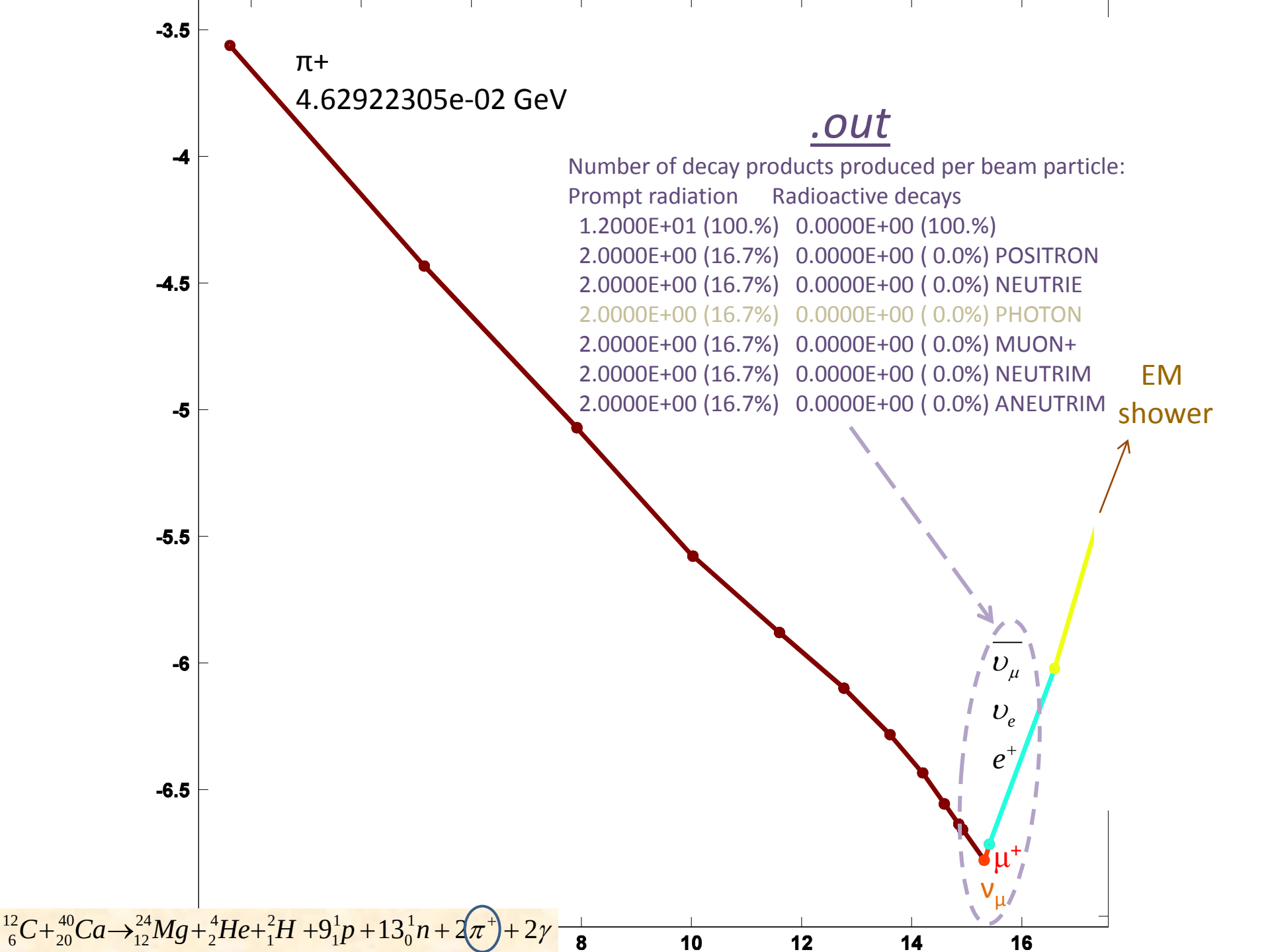


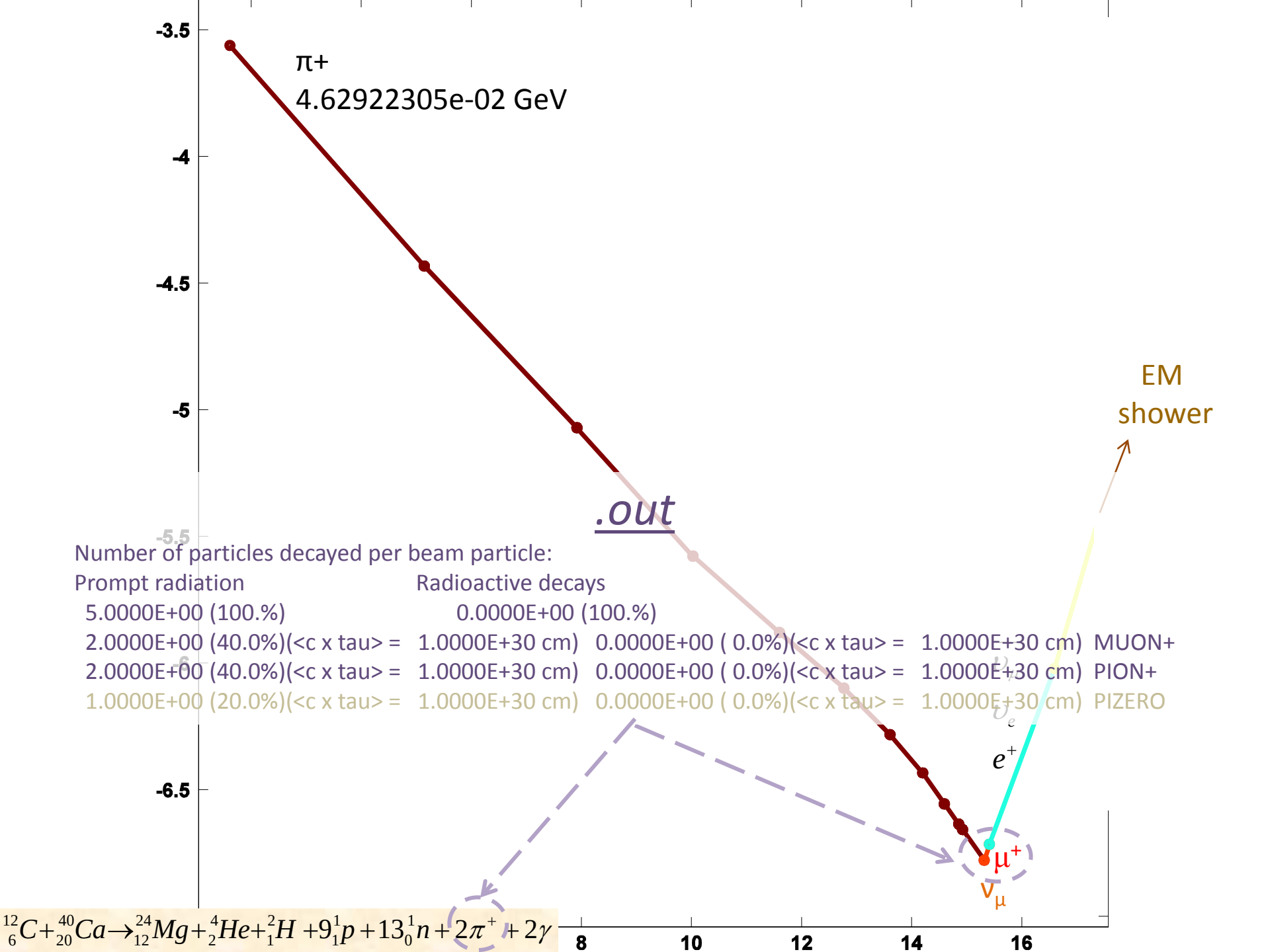
END PRODUCTS Tki (GeV)		
PHOTON	ELECTRON	PRODUCED FROM
	7.64209894e-04	pair production
2.95501173e-04	2.15497887e-04	Compton
2.53742037e-04	2.57257023e-04	
1.93167754e-04	3.05127382e-04	

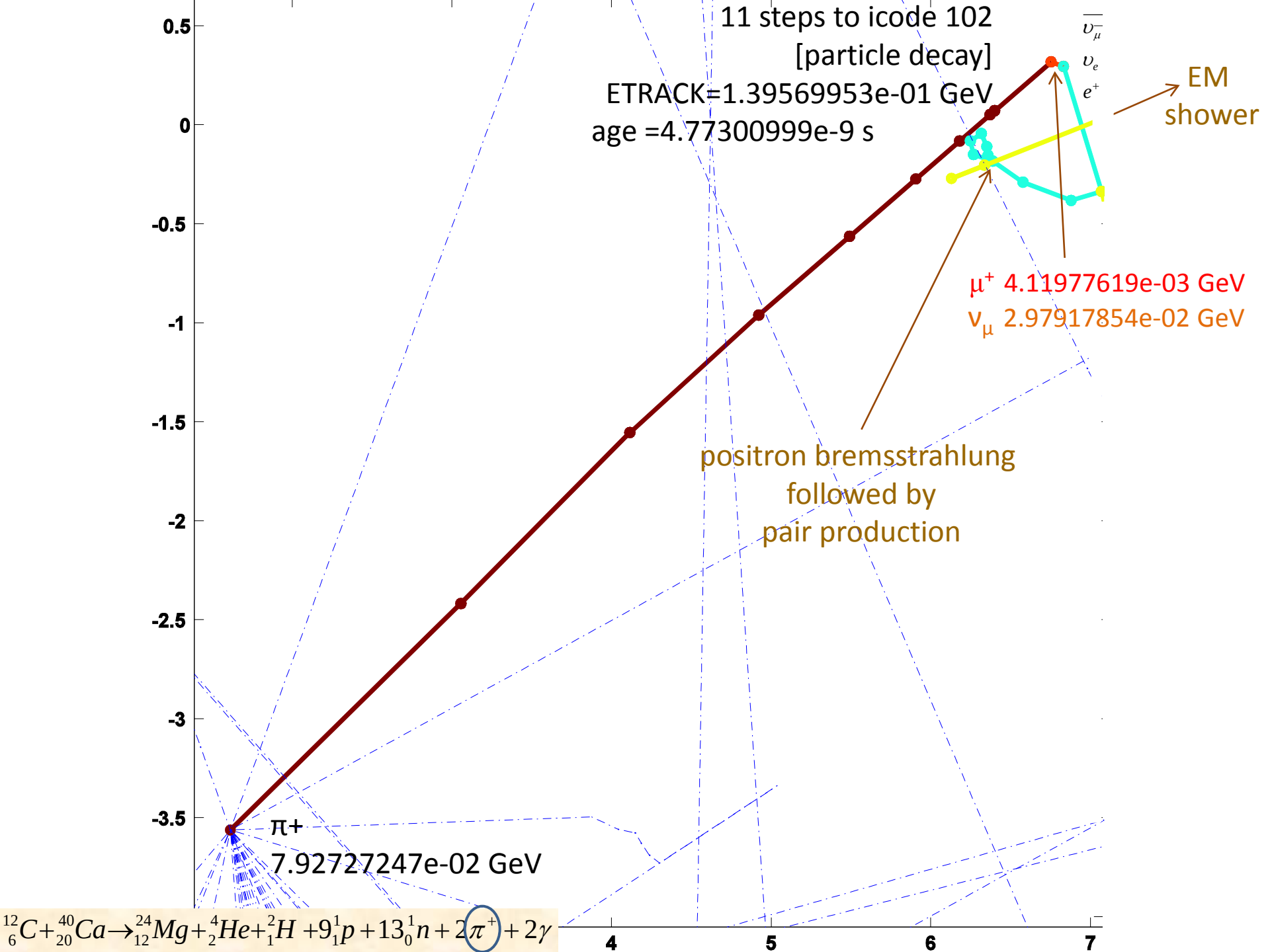
CUTOFFs Tki (GeV)	
3.33333333e-04	1.00000000e-03

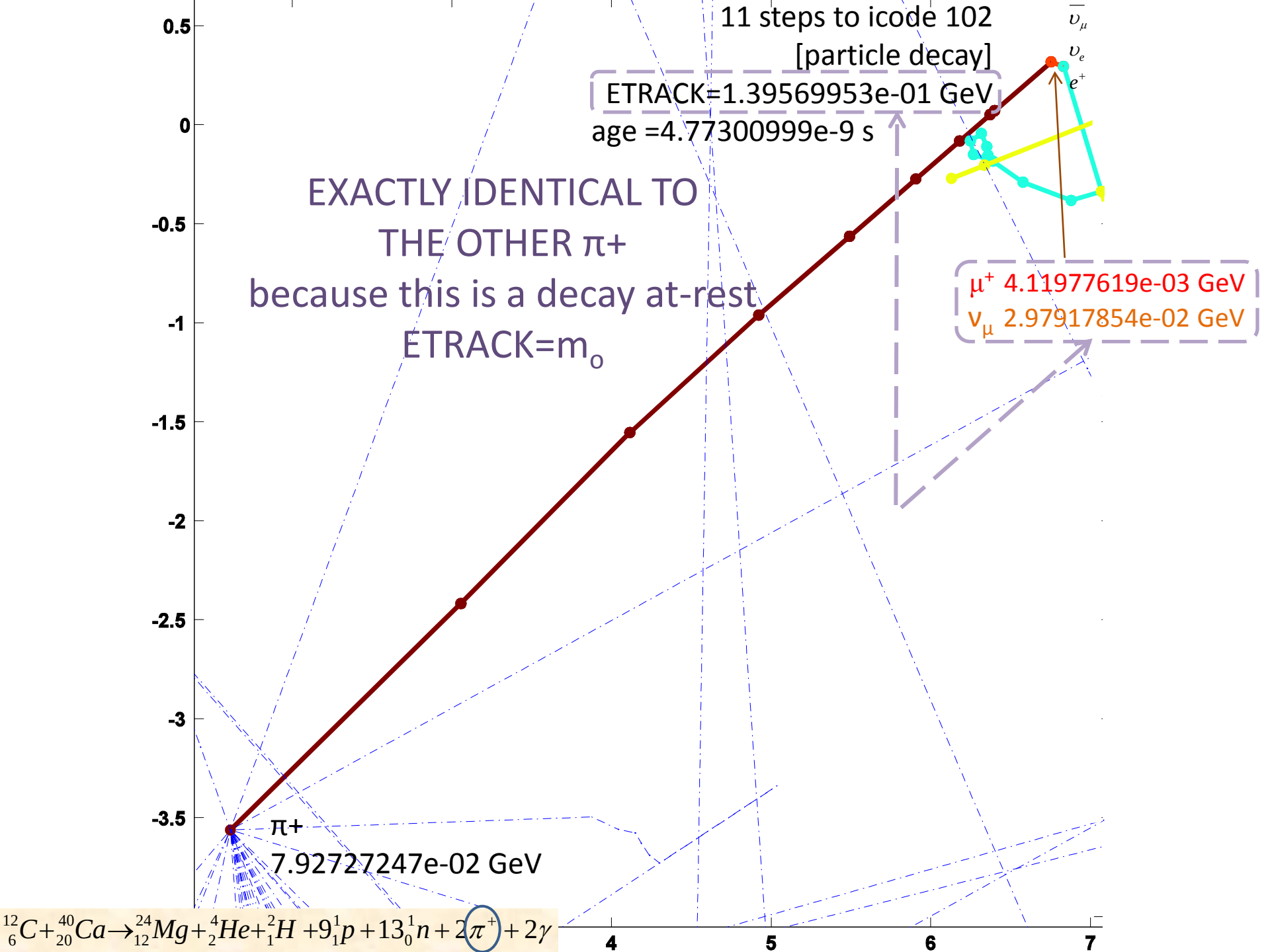
$$^{12}_{6}C + ^{40}_{20}Ca \rightarrow ^{24}_{12}Mg + ^{4}_{2}He + ^{2}_{1}H + 9\,^{1}_{1}p + 13\,^{1}_{0}n + 2\pi^{+} + 2\gamma$$

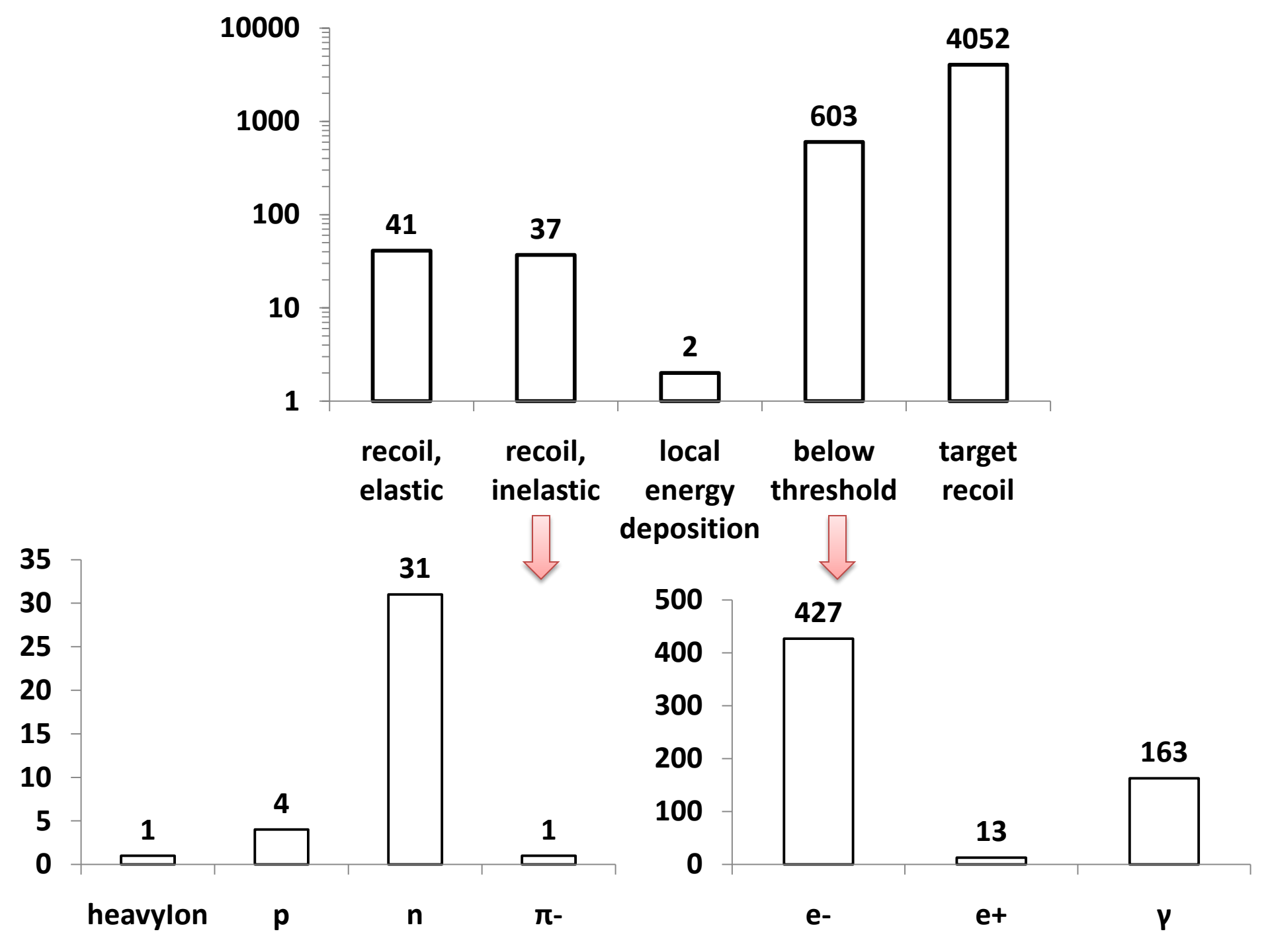

π+
4.62922305e-02 GeV
positron
bremsstrahlung
EM
shower
another
ICODE 102
$\overline{\upsilon_\mu}$
υ_e
e^+
11 steps to ICODE 102
[particle decay]
Etrack=1.39569953e-01 GeV
decay at rest: ETRACK=m$_o$
age =6.70014799e-08 s
μ+ 4.11977619e-03 GeV
ν$_μ$ 2.97917854e-02 GeV
$^{12}_{6}C+^{40}_{20}Ca\rightarrow^{24}_{12}Mg+^{4}_{2}He+^{2}_{1}H+9^{1}_{1}p+13^{1}_{0}n+2\pi^{+}+2\gamma$
-3.5
-4
-4.5
-5
-5.5
-6
-6.5
8
10
12
14
16


π+
4.62922305e-02 GeV
.out
Number of decay products produced per beam particle:
Prompt radiation Radioactive decays
1.2000E+01 (100.%) 0.0000E+00 (100.%)
2.0000E+00 (16.7%) 0.0000E+00 (0.0%) POSITRON
2.0000E+00 (16.7%) 0.0000E+00 (0.0%) NEUTRIE
2.0000E+00 (16.7%) 0.0000E+00 (0.0%) PHOTON
2.0000E+00 (16.7%) 0.0000E+00 (0.0%) MUON+
2.0000E+00 (16.7%) 0.0000E+00 (0.0%) NEUTRIM
2.0000E+00 (16.7%) 0.0000E+00 (0.0%) ANEUTRIM
EM shower
$\overline{\upsilon_\mu}$
υ_e
e^+
μ^+
ν_μ
-3.5
-4
-4.5
-5
-5.5
-6
-6.5
8
10
12
14
16
$^{12}_{6}C+^{40}_{20}Ca\rightarrow^{24}_{12}Mg+^{4}_{2}He+^{2}_{1}H+9^{1}_{1}p+13^{1}_{0}n+2\pi^{+}+2\gamma$


π+
4.62922305e-02 GeV
-3.5
-4
-4.5
-5
-5.5
-6
-6.5
8
10
12
14
16
.out
EM
shower
Number of particles decayed per beam particle:
Prompt radiation
Radioactive decays
5.0000E+00 (100.%)
0.0000E+00 (100.%)
2.0000E+00 (40.0%)(<c x tau> = 1.0000E+30 cm) 0.0000E+00 (0.0%)(<c x tau> = 1.0000E+30 cm) MUON+
2.0000E+00 (40.0%)(<c x tau> = 1.0000E+30 cm) 0.0000E+00 (0.0%)(<c x tau> = 1.0000E+30 cm) PION+
1.0000E+00 (20.0%)(<c x tau> = 1.0000E+30 cm) 0.0000E+00 (0.0%)(<c x tau> = 1.0000E+30 cm) PIZERO
$\bar{\nu}_e$
e^+
μ^+
ν_μ
$^{12}_{6}C+^{40}_{20}Ca\rightarrow^{24}_{12}Mg+^{4}_{2}He+^{2}_{1}H+9^{1}_{1}p+13^{1}_{0}n+2\pi^{+}+2\gamma$


11 steps to icode 102
[particle decay]
ETRACK=1.39569953e-01 GeV
age =4.77300999e-9 s
$\overline{\nu_\mu}$
ν_e
e^+
EM shower
μ+ 4.11977619e-03 GeV
νμ 2.97917854e-02 GeV
positron bremsstrahlung
followed by
pair production
π+
7.92727247e-02 GeV
$^{12}_{6}C+^{40}_{20}Ca\rightarrow^{24}_{12}Mg+^{4}_{2}He+^{2}_{1}H+9^{1}_{1}p+13^{1}_{0}n+2\pi^{+}+2\gamma$


11 steps to icode 102
[particle decay]
ETRACK=1.39569953e-01 GeV
age =4.77300999e-9 s
EXACTLY IDENTICAL TO
THE OTHER π+
because this is a decay at-rest
ETRACK=m$_o$
μ+ 4.11977619e-03 GeV
ν$_\mu$ 2.97917854e-02 GeV
π+
7.92727247e-02 GeV
$^{12}_{6}C+^{40}_{20}Ca\rightarrow^{24}_{12}Mg+^{4}_{2}He+^{2}_{1}H+9^{1}_{1}p+13^{1}_{0}n+2\pi^{+}+2\gamma$


10000
1000
100
10
1
41
37
2
603
4052
recoil, elastic
recoil, inelastic
local energy deposition
below threshold
target recoil
35
30
25
20
15
10
5
0
1
4
31
1
heavylon
p
n
π-
500
400
300
200
100
0
427
13
163
e-
e+
γ

FULFILLING THE COURSE REQUIREMENTS

> Date: Thu, 17 Jun 2010 15:22:19
> From: Vasilis Vlachoudis<Vasilis.Vlachoudis@cern.ch>
>
> Dear Contributor,
>
> we are happy to announce you that on the basis of the abstract you
> submitted we allocated a 30min slot for your presentation (including
> 8min of discussion) in the program of the workshop taking place along
> with the 1st FLUKA advanced course.
>
> We would like to point out that special emphasis should be given to:
> - the technical implementation of the simulation carried out;
> - the evaluation of main sources of uncertainties;
> - comparison with experimental outcome when available;
> - possible open points for further discussion;
>
> The presentation should be intended in a didactive style more than as
> a conference talk.
>
> Looking forward seeing you in Portugal
>
> The FLUKA course team

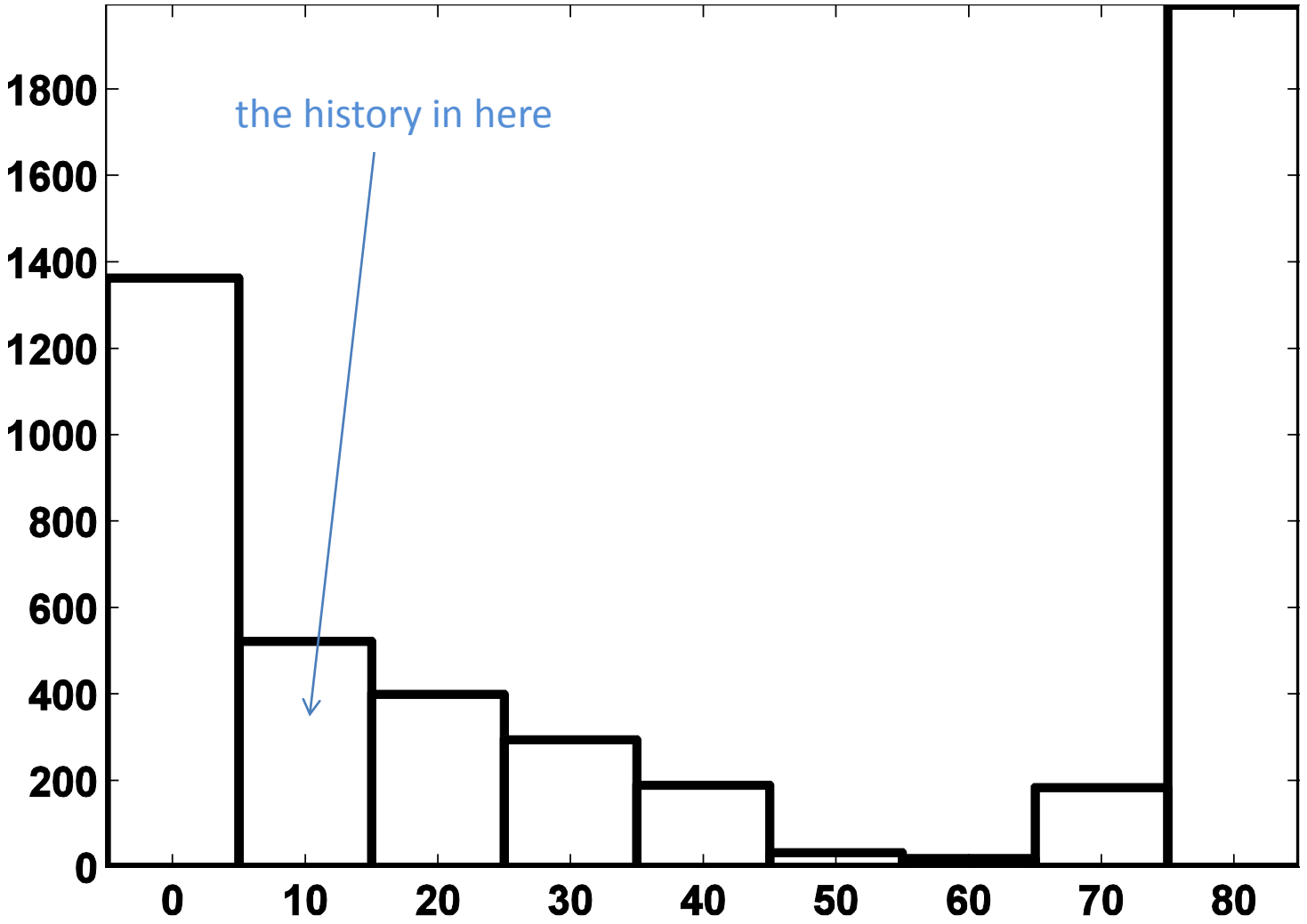
MY UNCERTAINTY = 100%

THIS HISTORY

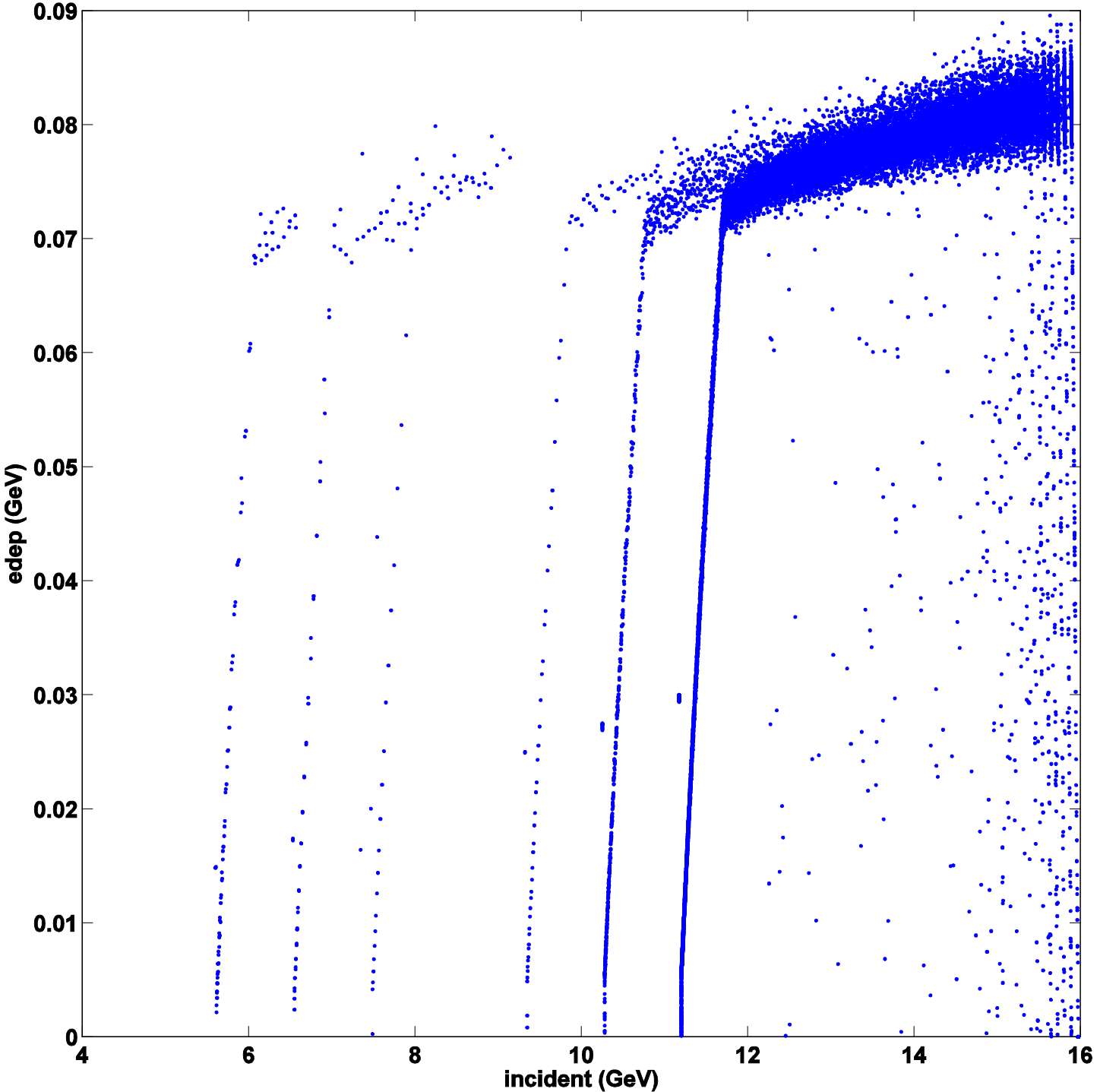
(in no way representative)

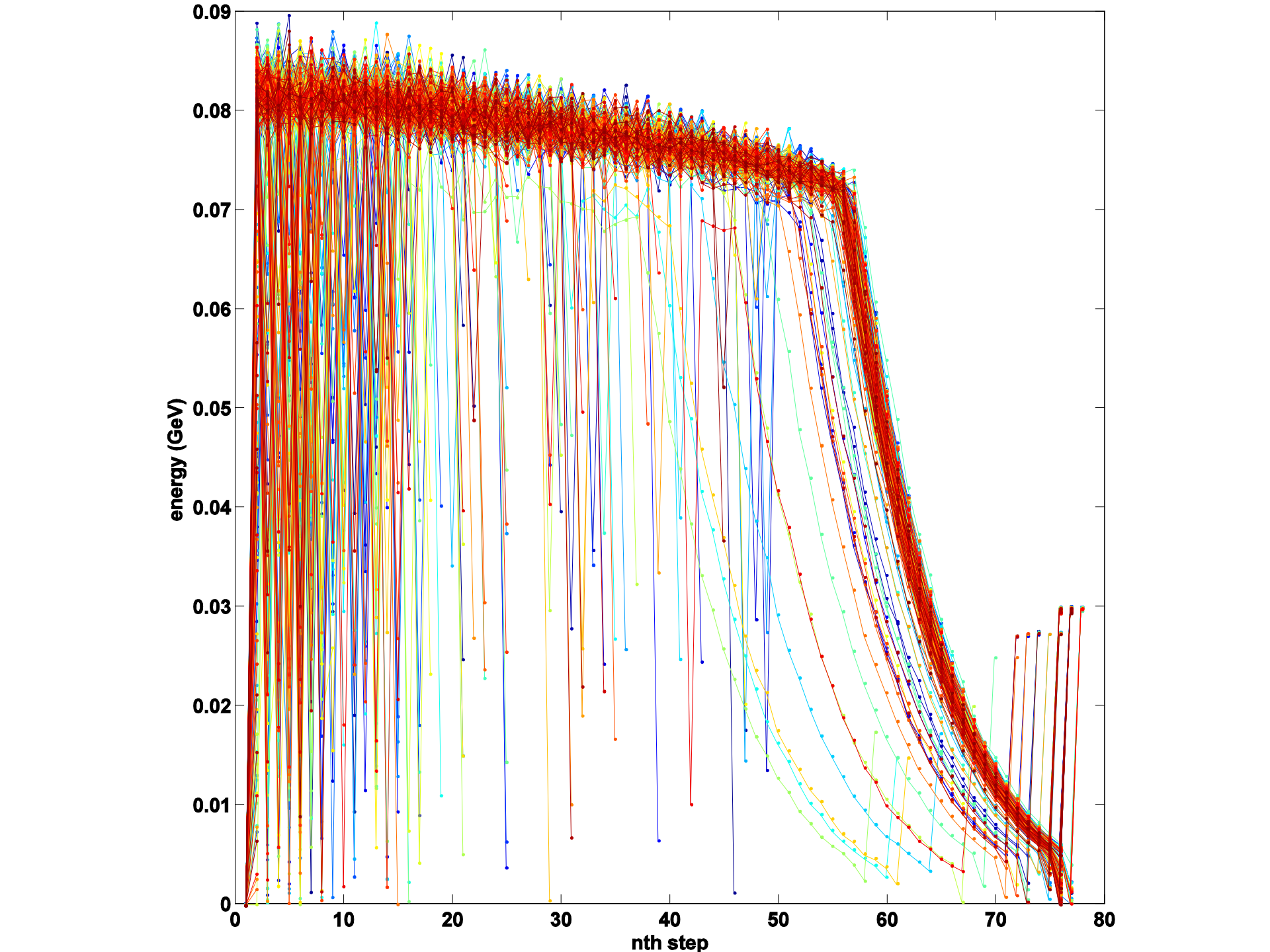
IN THE CONTEXT OF

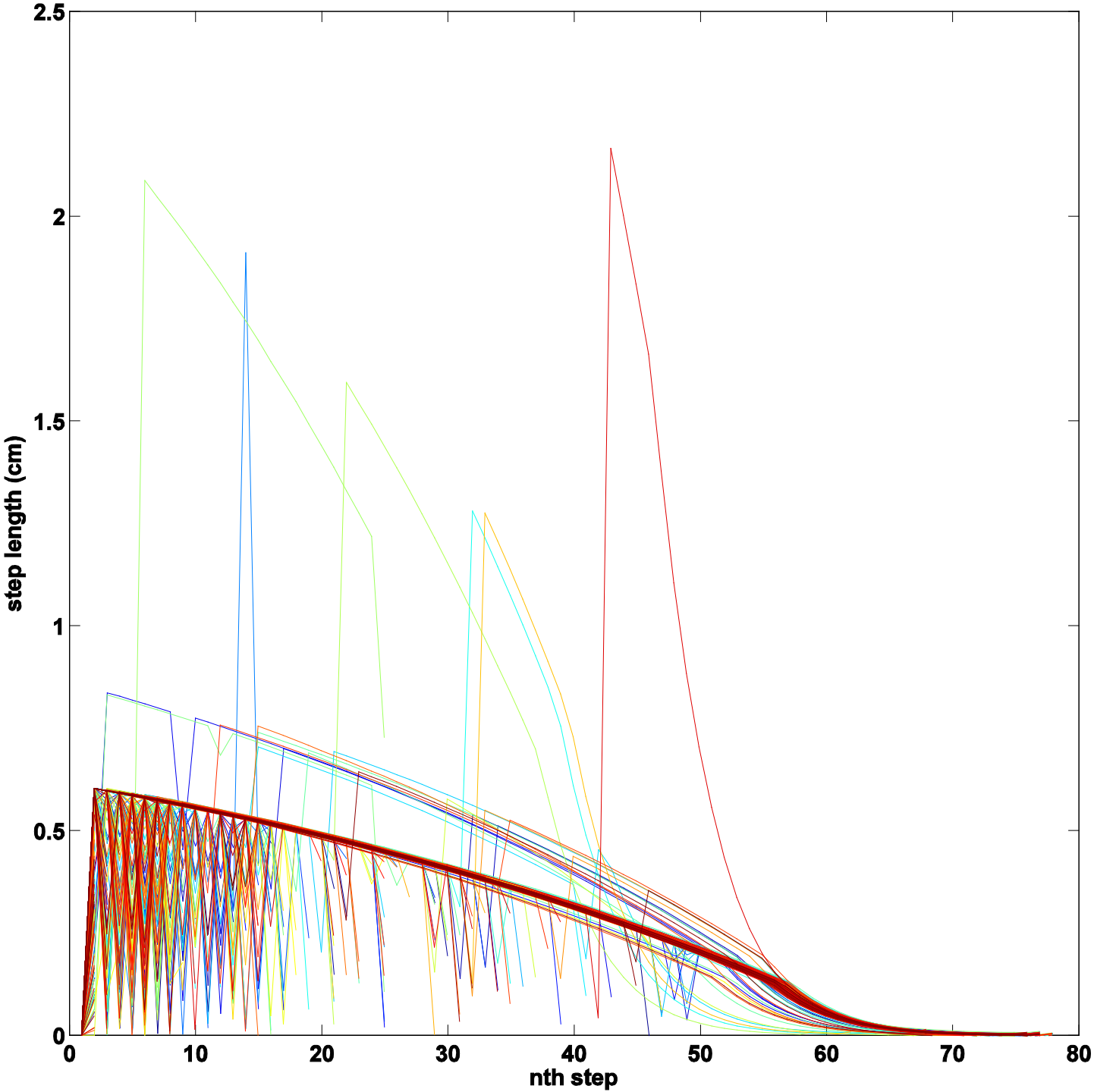
THE OTHER HISTORIES

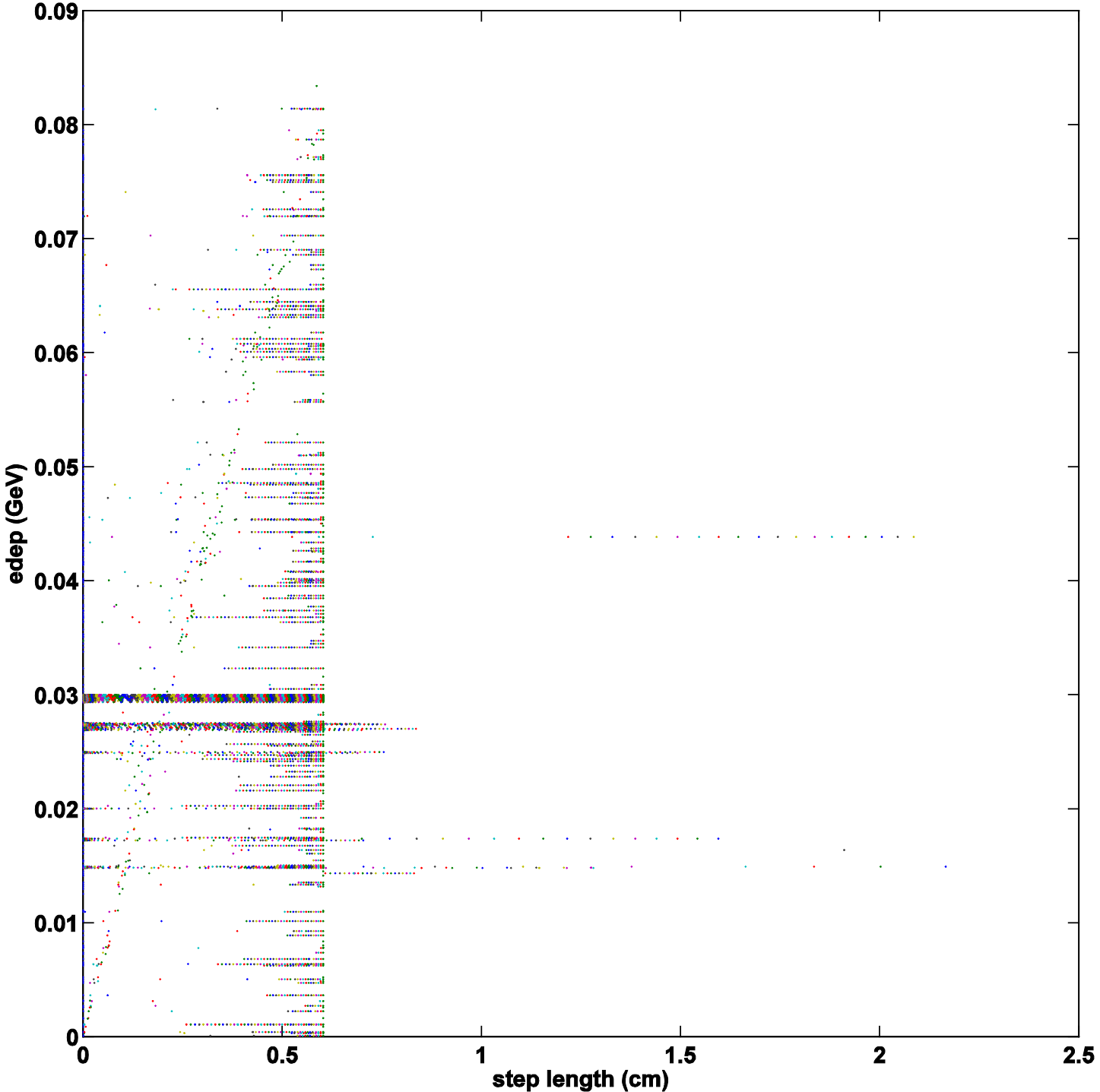


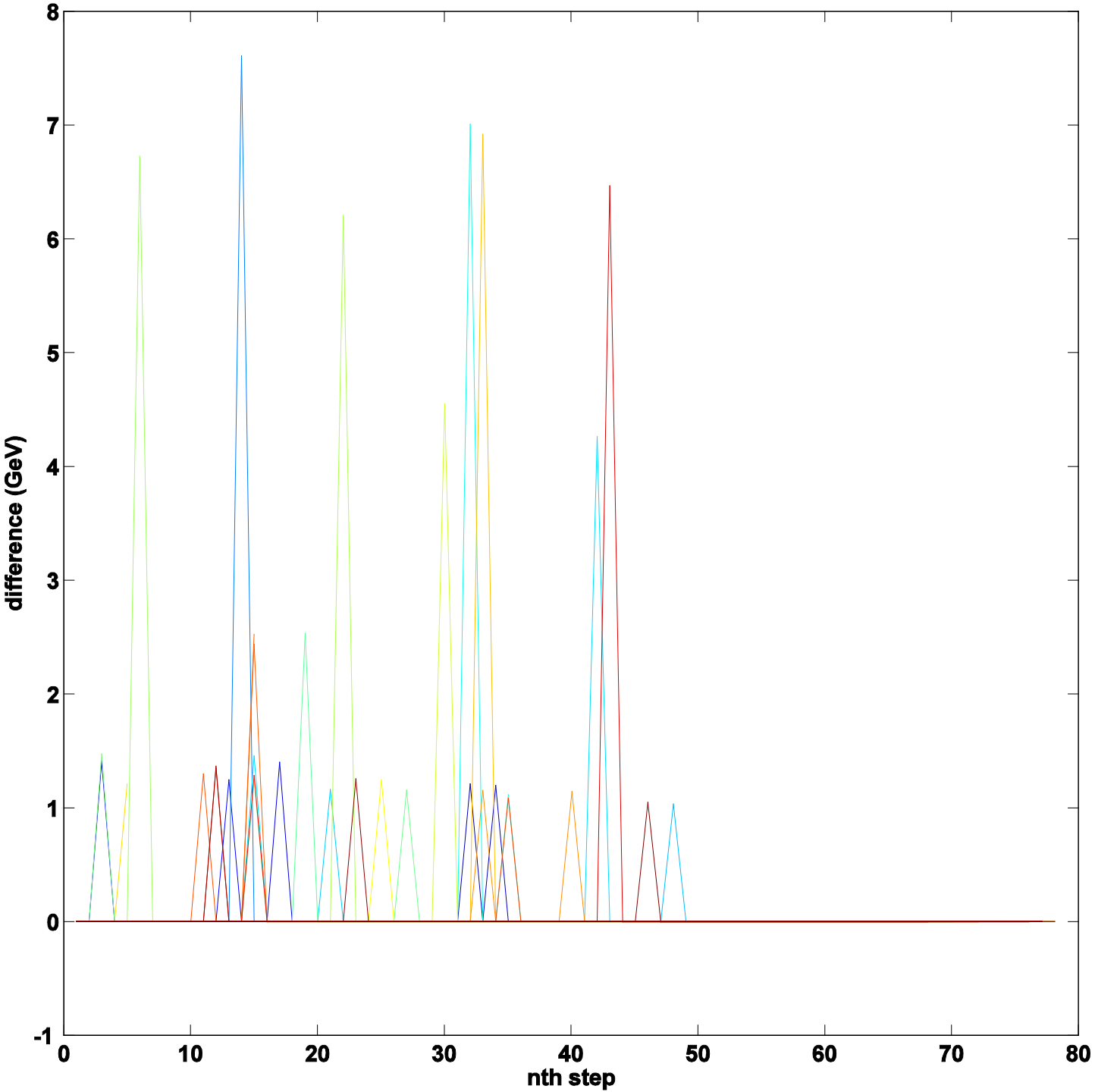
^{12}C steps before absorption / collision


edep (GeV)
incident (GeV)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
4
6
8
10
12
14
16


energy (GeV)
nth step
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0
10
20
30
40
50
60
70
80


step length (cm)
nth step
0
0.5
1
1.5
2
2.5
0
10
20
30
40
50
60
70
80


edep (GeV)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.5
1
1.5
2
2.5
step length (cm)


8
7
6
5
4
3
2
1
0
-1
difference (GeV)
0
10
20
30
40
50
60
70
80
nth step