The Compton polarimeter in IR6

Zhengqiao Zhang
BNL

How to choose the position of electron polarimeter and Compton IP

- **Have a dipole to separate the scattered photons from the beam;**
- **As close to the ep IP as possible;**
- **Enough rate of scattered photons;**
- **Small smearing in Y position;**
- **Detect scattered photons and recoil electrons;**

Luminosity and Y smearing

$$L = f_b N_e N_\gamma G$$

Geometric factor:

$$G = \frac{1 + \beta cos\theta}{2\pi\sqrt{\sigma_y^2 + \sigma_{\gamma y}^2}\sqrt{\sigma_x^2(\beta + cos\theta)^2 + \sigma_{\gamma x}^2(1 + \beta cos\theta)^2 + (\sigma_z^2 + \sigma_{\gamma z}^2)sin^2\theta}}$$

$f_b = 2.2852 \times 10^7; Ne = 6.2 \times 10^{10}; N_\gamma = 2.84974 \times 10^{12};$

$\sigma_{\gamma x} = 0.1mm; \sigma_{\gamma y} = 0.1mm; \sigma_{\gamma z} = 1.3mm;$

$\sigma_z = 10mm; \sigma_x = \sqrt{\epsilon_x \beta_x}, \beta_x = 13.4m; \beta_y = 19m;$

$\delta P_e \approx \frac{1}{A\sqrt{N}}; N = time * L * \sigma_{Compton} * 0.8 * f_b/290;$

$\theta = 3mrad; \sigma_{Compton} = 400mb;$

The distribution of the initial electrons would also produce a smearing of the Y distribution of the scattered photon; The height of the electron beam at a distance D from the IP is calculated in the following way:

$$\sigma_{e,y}(D) = \sqrt{\epsilon_y \beta_y(D)} = \sqrt{\epsilon_y}\sqrt{\beta_y(0) - 2\alpha_y(0)D + \gamma_y(0)D^2}$$

$$\gamma_y(0) = \frac{1 + \alpha_y^2(0)}{\beta_y(0)}$$

Transporting Twiss Parameters

The emittance between two points is conserved, regardless of the change in beam shape and orientation, so the twins parameters transform as:

$$\begin{pmatrix} \beta \\ \alpha \\ \gamma \end{pmatrix} = \begin{pmatrix} C^2 & -2SC & S^2 \\ -CC' & (S'C + SC') & -SS' \\ C'^2 & -2S'C' & S'^2 \end{pmatrix} \begin{pmatrix} \beta_o \\ \alpha_o \\ \gamma_o \end{pmatrix}$$

For drift: $M_{\text{twiss, drift}} = \begin{pmatrix} 1 & -2L & L^2 \\ 0 & 1 & -L \\ 0 & 0 & 1 \end{pmatrix}$ →

$$\beta = \beta_o - 2L\alpha_o + L^2\gamma_o$$
$$\alpha = \alpha_o - L\gamma_o$$
$$\gamma = \gamma_o$$

For Quadrupole:

If K>0

$$C(s) = \cos(\sqrt{K}s), \quad S(s) = \frac{1}{\sqrt{K}}\sin(\sqrt{K}s).$$

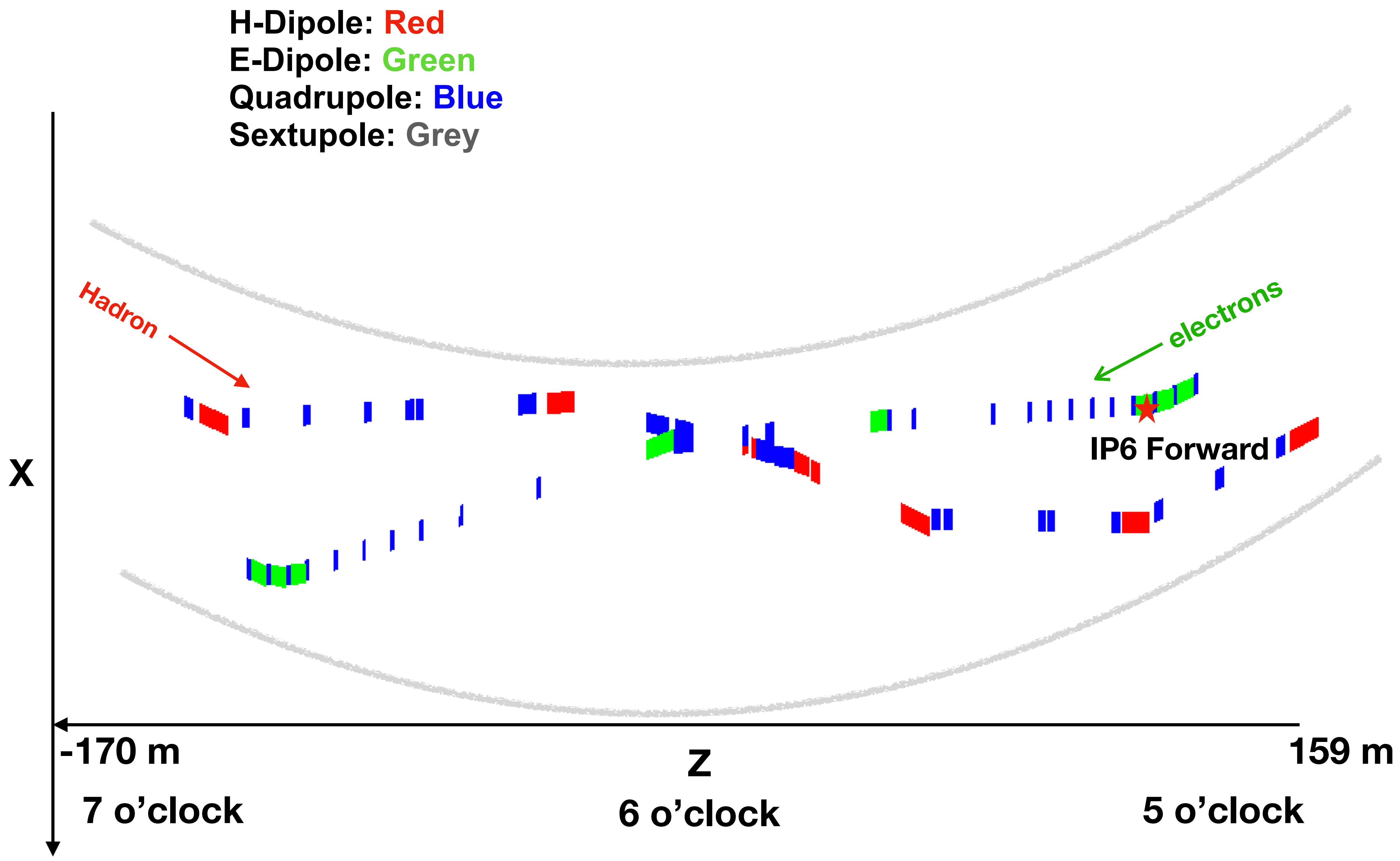
If K<0

$$C(s) = \cosh(\sqrt{K}s), \quad S(s) = \frac{1}{\sqrt{K}}\sinh(\sqrt{K}s)$$

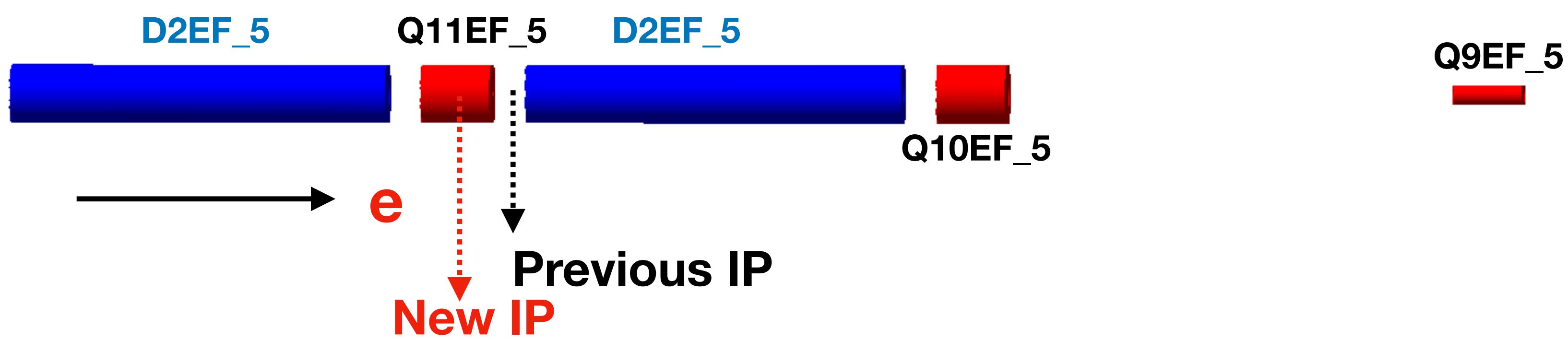
→

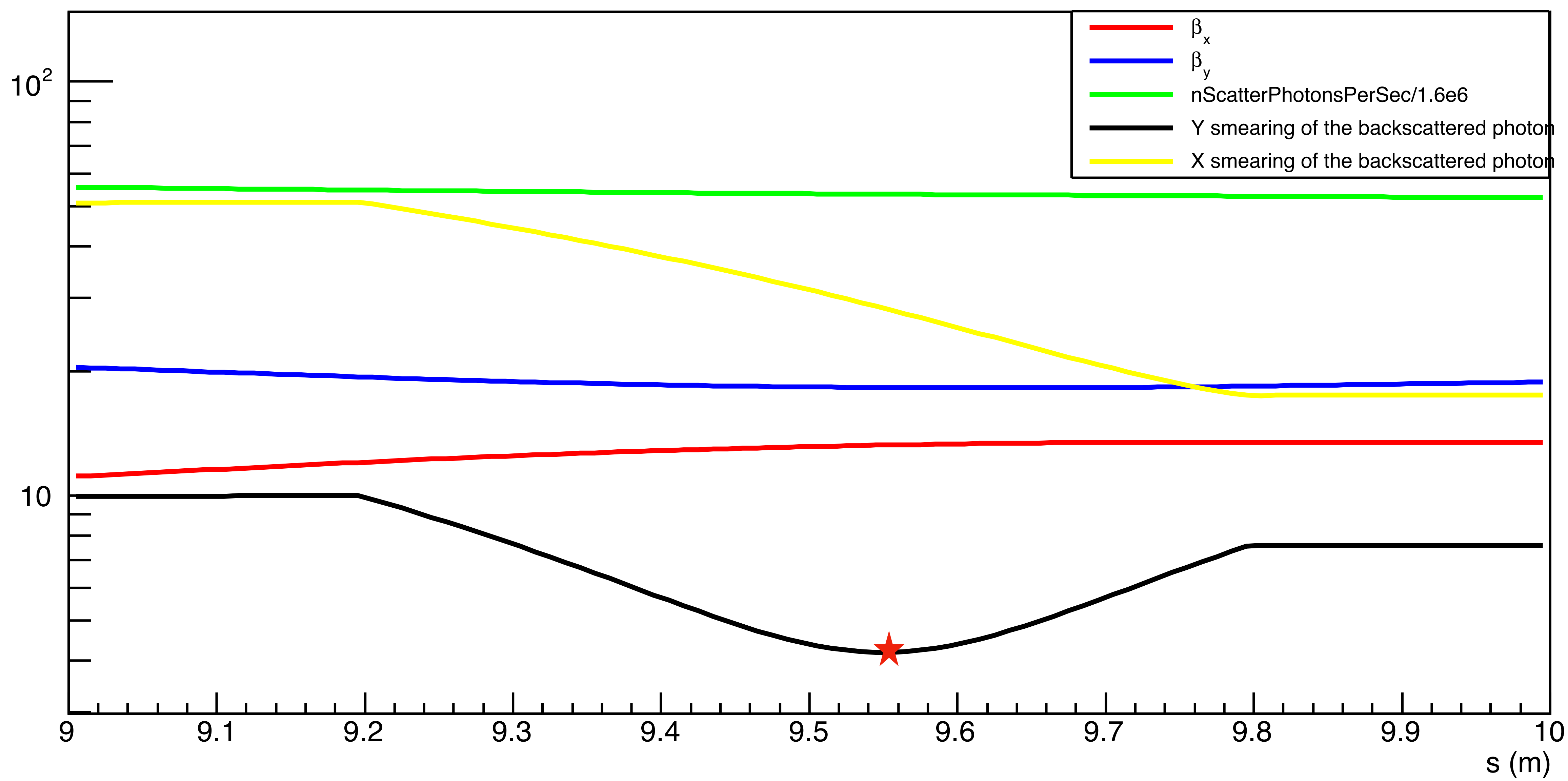
$$\beta(s) = C^2\beta_0 - 2CS\alpha_0 + S^2\gamma_0$$
$$\alpha(s) = -CC'\beta_0 + (SC' + S'C)\alpha_0 - SS'\gamma_0$$
$$\gamma(s) = C'^2\beta_0 - 2S'C'\alpha_0 + S'^2\gamma_0$$

IR6 layout

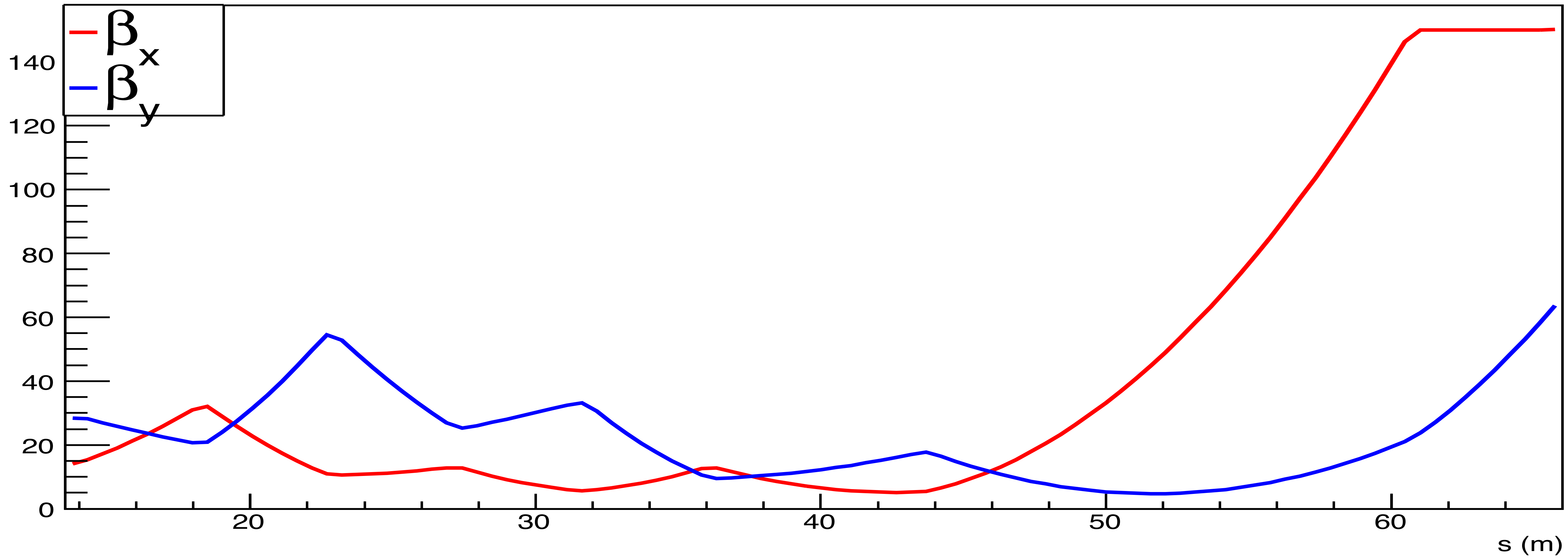

H-Dipole: Red
E-Dipole: Green
Quadrupole: Blue
Sextupole: Grey
Hadron
electrons
IP6 Forward
X
-170 m
Z
159 m
7 o'clock
6 o'clock
5 o'clock

Optimize IP6 Forward Compton IP

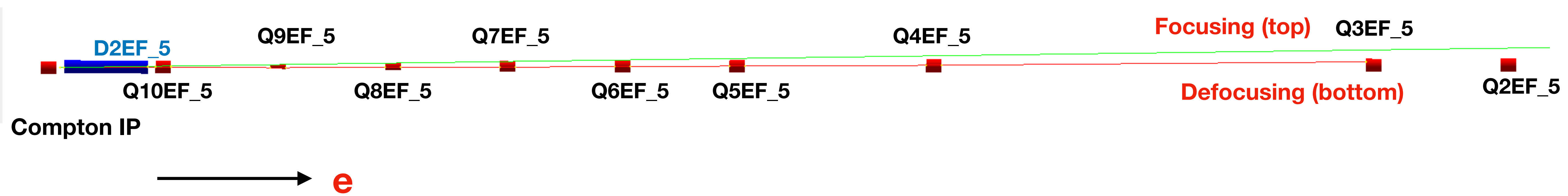




IP6 Forward

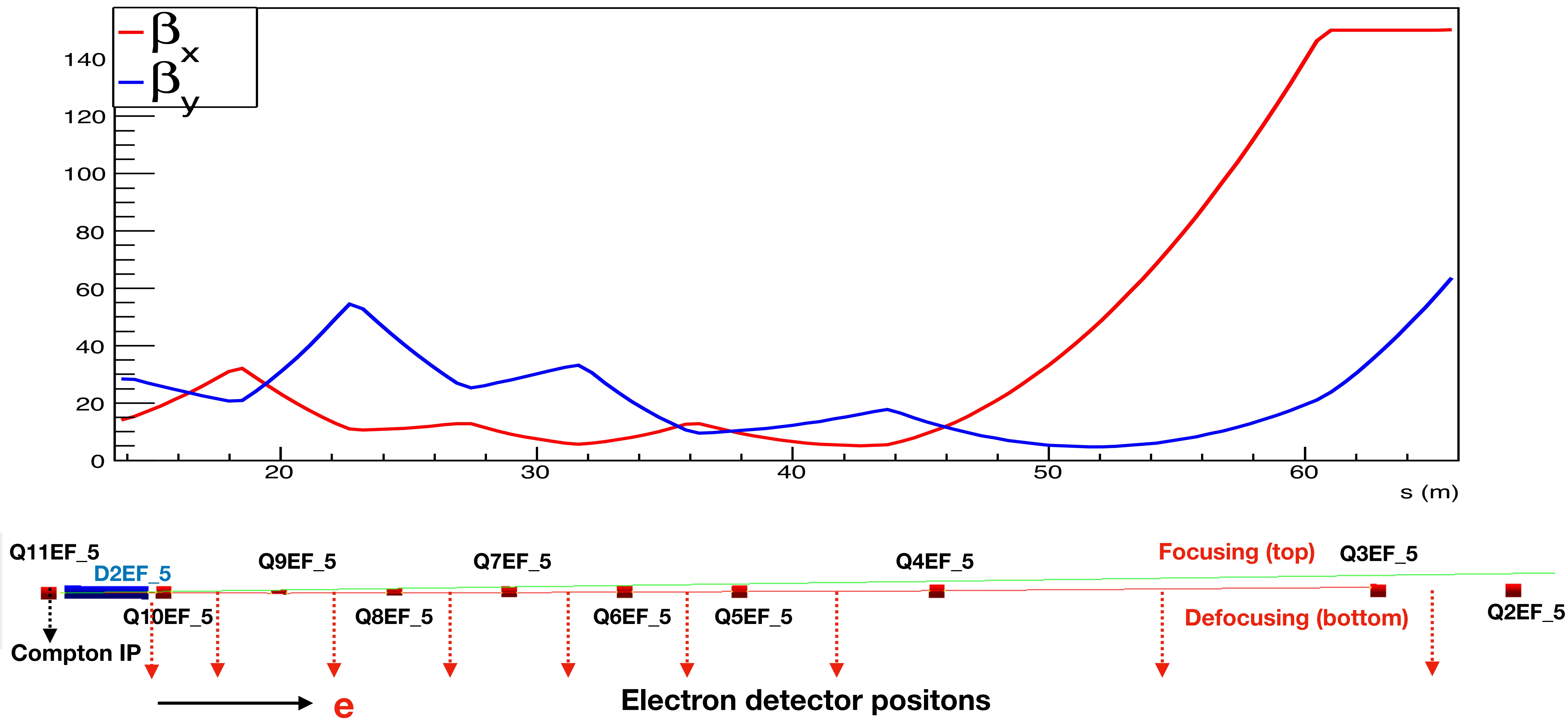


βx
βy
140
120
100
80
60
40
20
0
20
30
40
50
60
s (m)

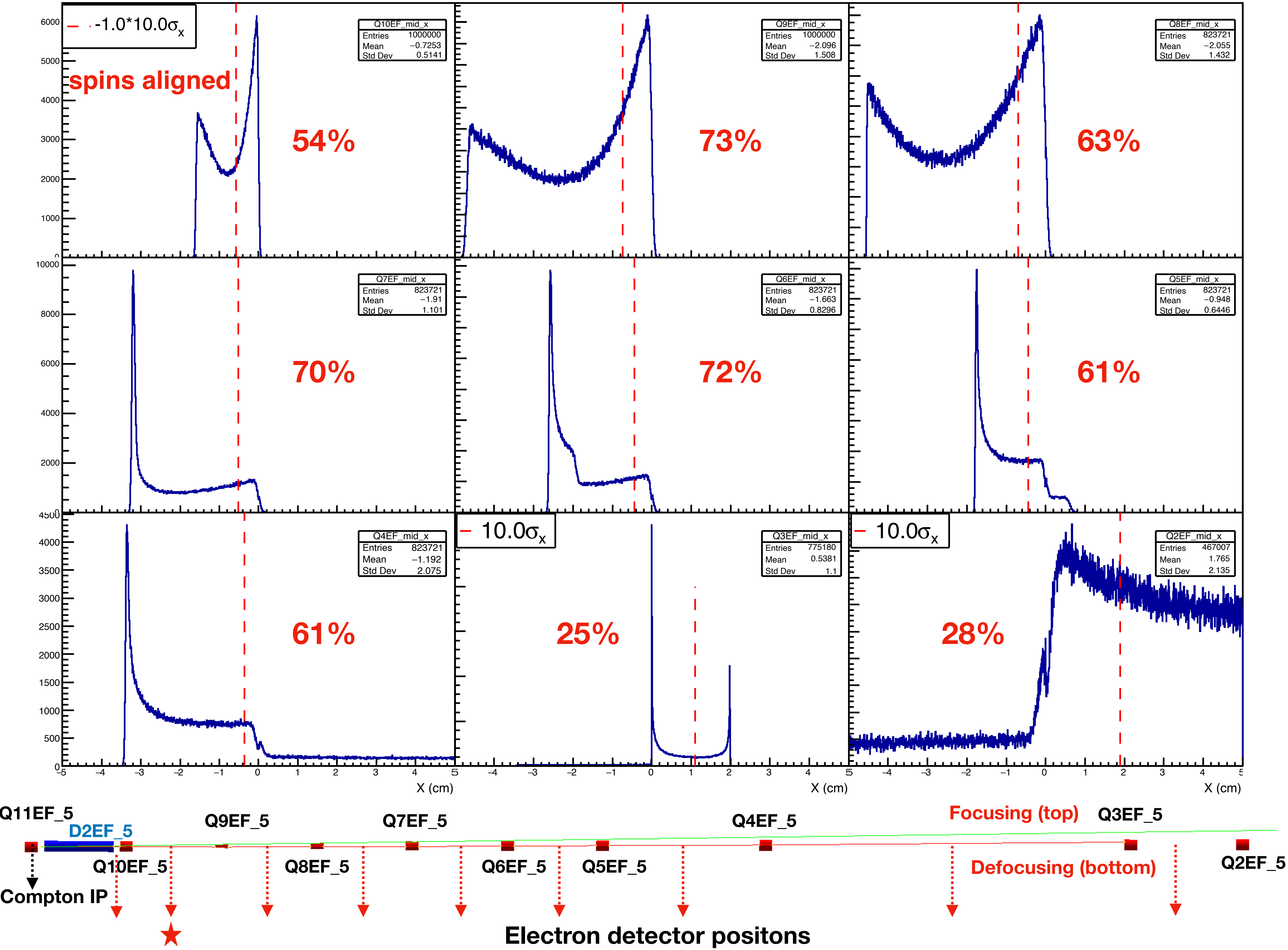


D2EF_5
Q9EF_5
Q7EF_5
Q4EF_5
Focusing (top)
Q3EF_5
Q10EF_5
Q8EF_5
Q6EF_5
Q5EF_5
Defocusing (bottom)
Q2EF_5
Compton IP
e

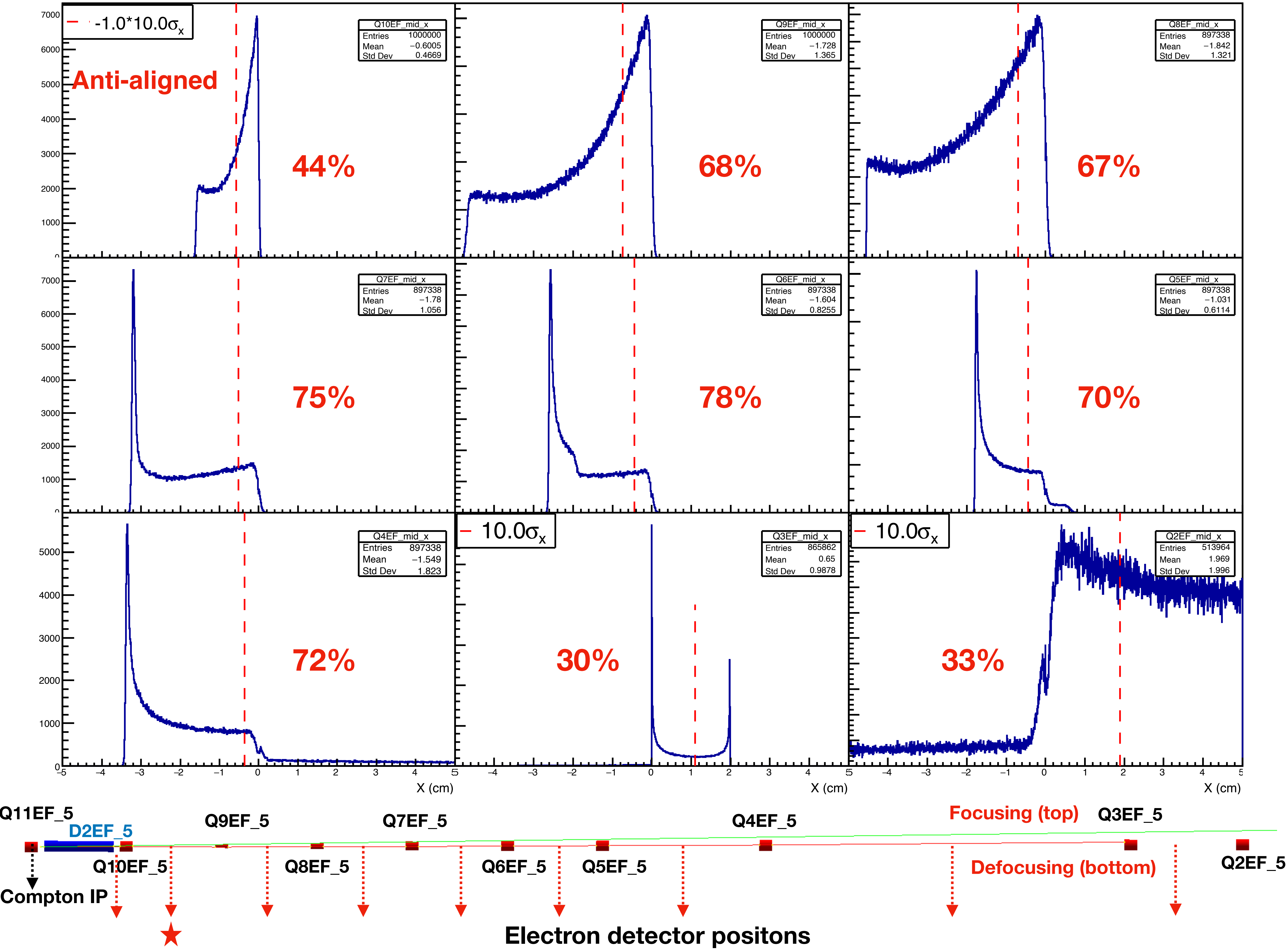
IP6 Forward



β_x
β_y
140
120
100
80
60
40
20
0
20
30
40
50
60
s (m)
Q11EF_5
D2EF_5
Q9EF_5
Q7EF_5
Q4EF_5
Focusing (top)
Q3EF_5
Q10EF_5
Q8EF_5
Q6EF_5
Q5EF_5
Defocusing (bottom)
Q2EF_5
Compton IP
e
Electron detector positons



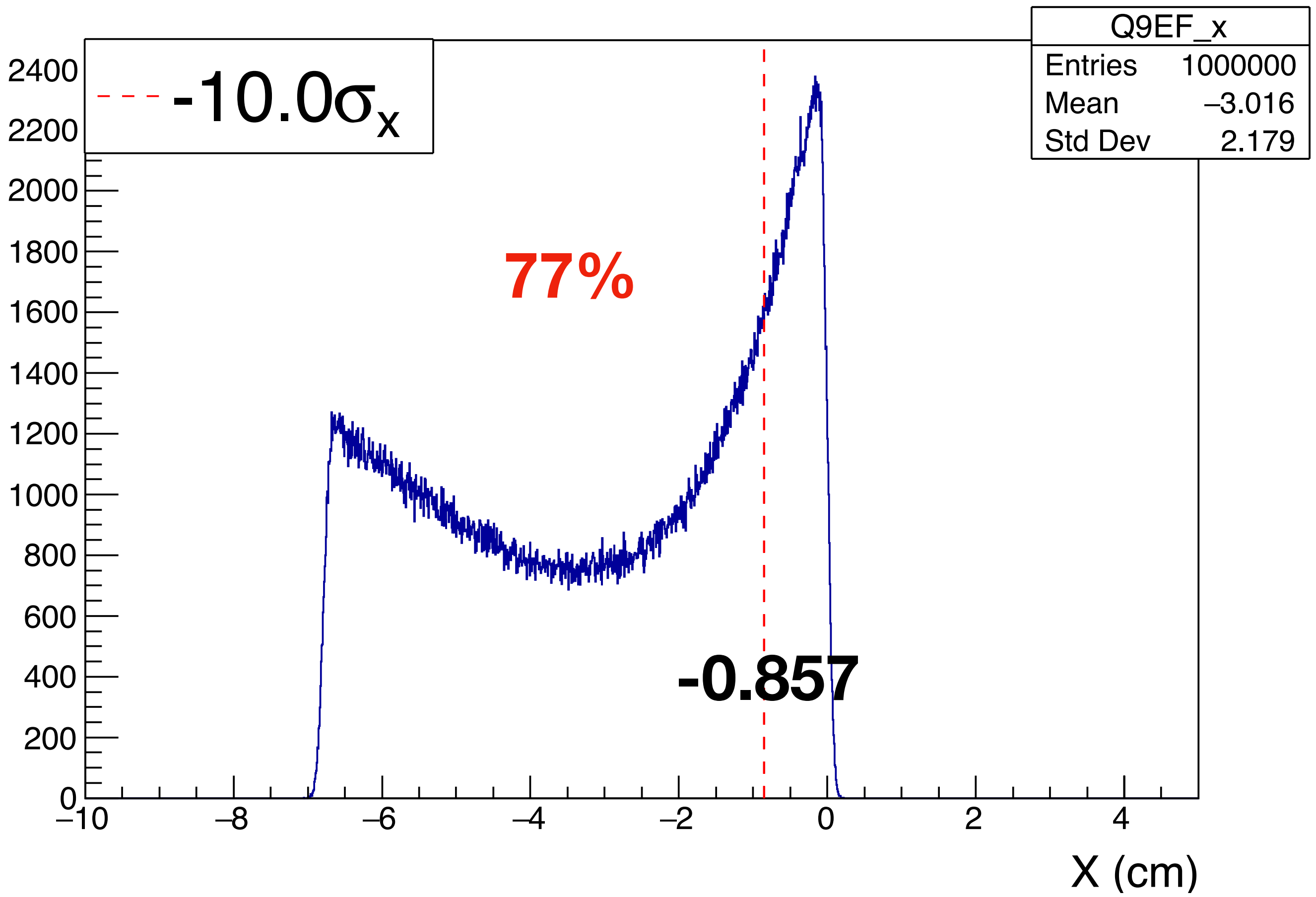
-1.0*10.0σ_x
spins aligned
Q10EF_mid_x
Entries 1000000
Mean −0.7253
Std Dev 0.5141
54%
Q9EF_mid_x
Entries 1000000
Mean −2.096
Std Dev 1.508
73%
Q8EF_mid_x
Entries 823721
Mean −2.055
Std Dev 1.432
63%
Q7EF_mid_x
Entries 823721
Mean −1.91
Std Dev 1.101
70%
Q6EF_mid_x
Entries 823721
Mean −1.663
Std Dev 0.8296
72%
Q5EF_mid_x
Entries 823721
Mean −0.948
Std Dev 0.6446
61%
Q4EF_mid_x
Entries 823721
Mean −1.192
Std Dev 2.075
61%
10.0σ_x
Q3EF_mid_x
Entries 775180
Mean 0.5381
Std Dev 1.1
25%
10.0σ_x
Q2EF_mid_x
Entries 467007
Mean 1.765
Std Dev 2.135
28%
X (cm)
X (cm)
X (cm)
Q11EF_5
D2EF_5
Q9EF_5
Q7EF_5
Q4EF_5
Focusing (top)
Q3EF_5
Q10EF_5
Q8EF_5
Q6EF_5
Q5EF_5
Defocusing (bottom)
Q2EF_5
Compton IP
Electron detector positons



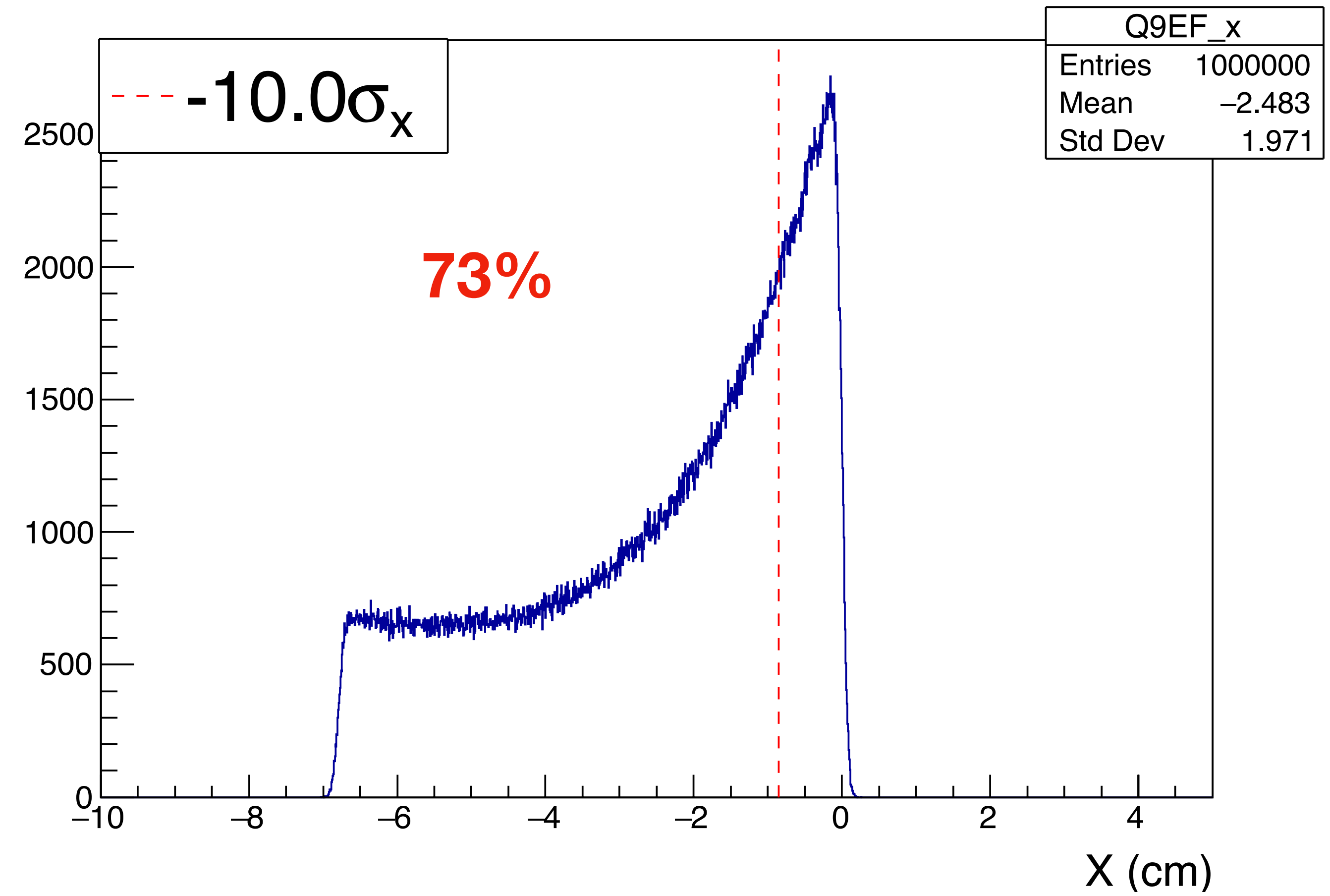
-1.0*10.0σx
Anti-aligned
Q10EF_mid_x Entries 1000000 Mean −0.6005 Std Dev 0.4669
44%
Q9EF_mid_x Entries 1000000 Mean −1.728 Std Dev 1.365
68%
Q8EF_mid_x Entries 897338 Mean −1.842 Std Dev 1.321
67%
Q7EF_mid_x Entries 897338 Mean −1.78 Std Dev 1.056
75%
Q6EF_mid_x Entries 897338 Mean −1.604 Std Dev 0.8255
78%
Q5EF_mid_x Entries 897338 Mean −1.031 Std Dev 0.6114
70%
Q4EF_mid_x Entries 897338 Mean −1.549 Std Dev 1.823
72%
10.0σx
Q3EF_mid_x Entries 865862 Mean 0.65 Std Dev 0.9878
30%
10.0σx
Q2EF_mid_x Entries 513964 Mean 1.969 Std Dev 1.996
33%
X (cm)
X (cm)
X (cm)
Q11EF_5
D2EF_5
Q9EF_5
Q7EF_5
Q4EF_5
Focusing (top)
Q3EF_5
Q10EF_5
Q8EF_5
Q6EF_5
Q5EF_5
Defocusing (bottom)
Q2EF_5
Compton IP
Electron detector positons

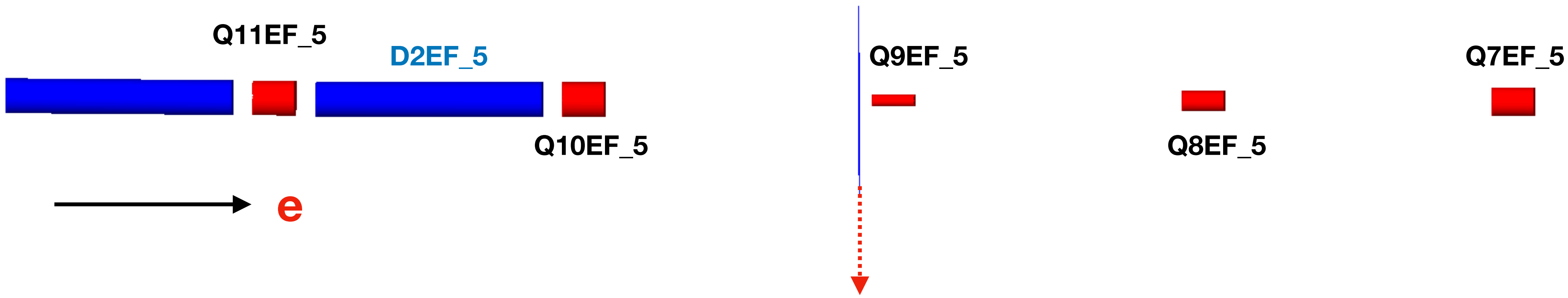
Electron detection

spins aligned



Anti-aligned

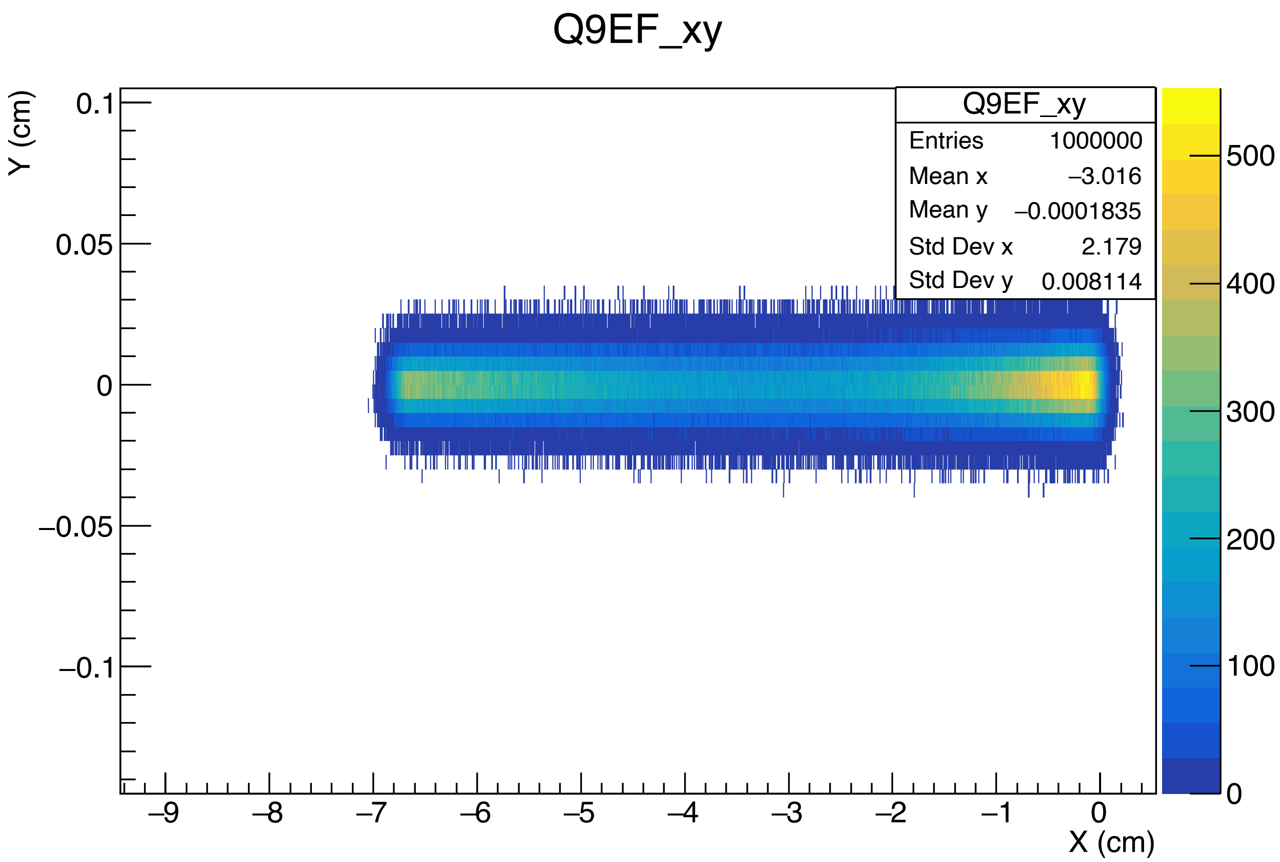




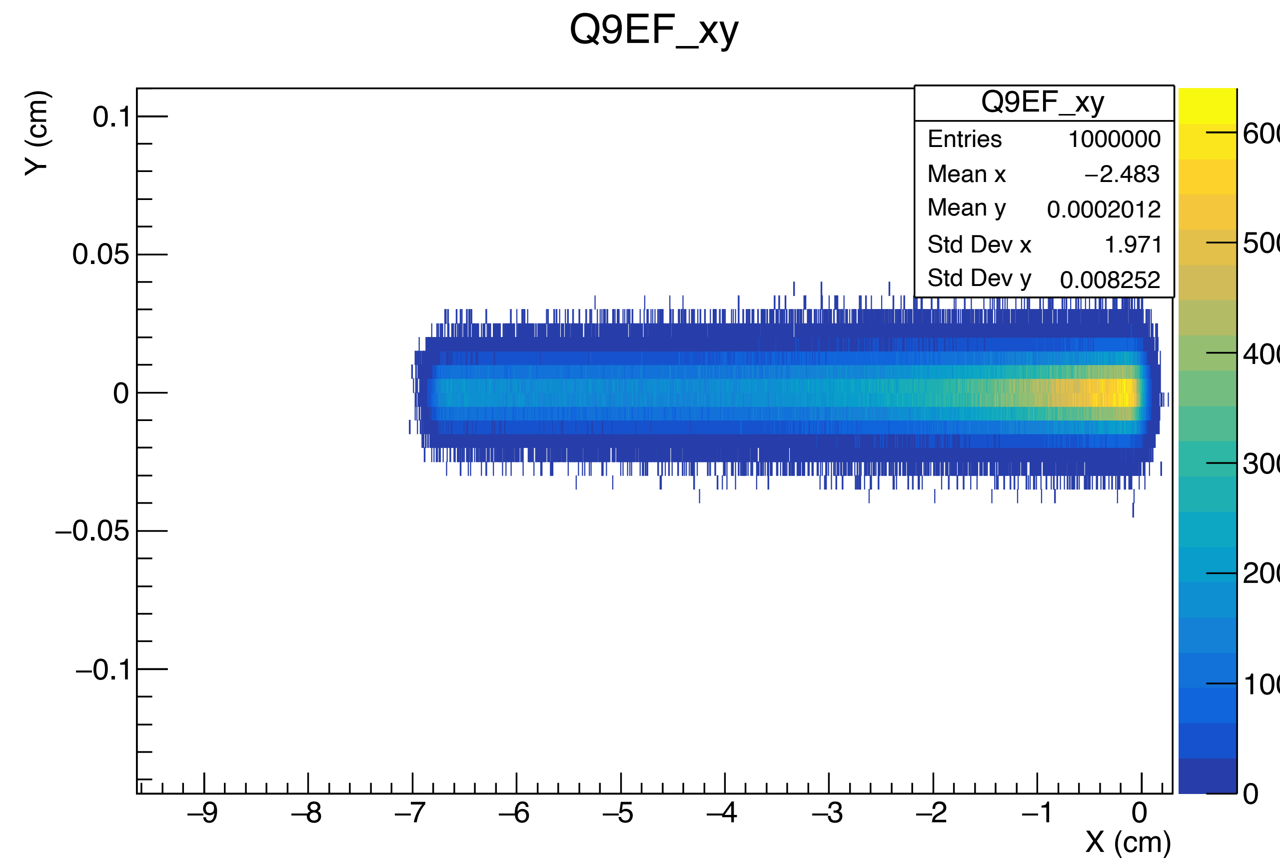
Electron detector positons

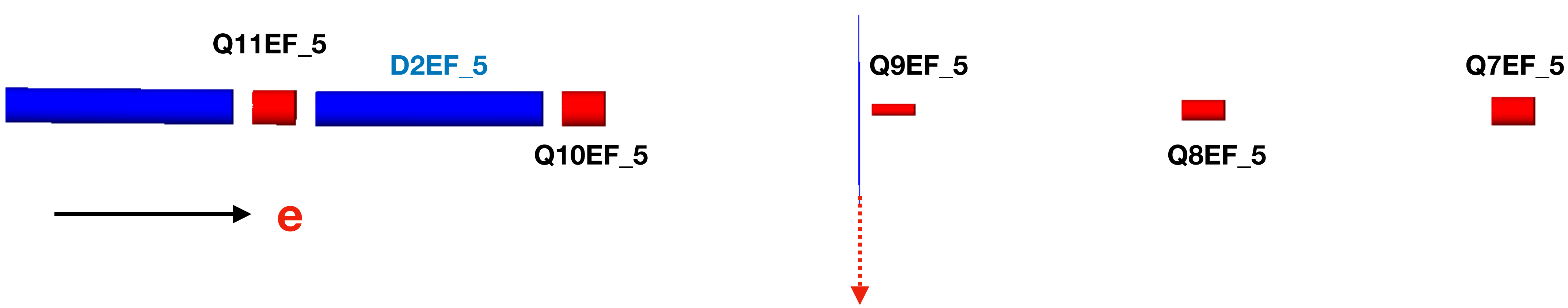
Electron detection

spins aligned



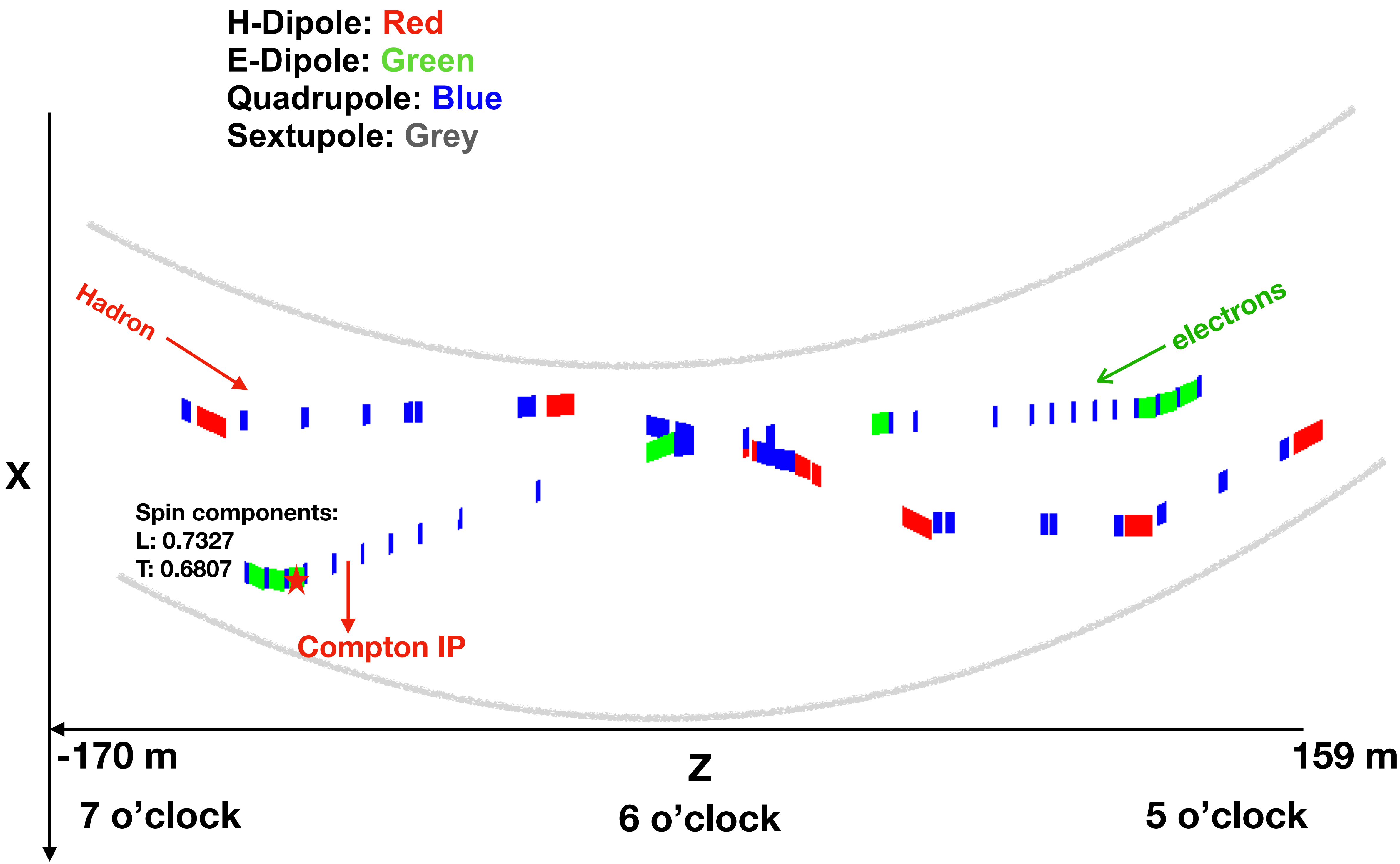
Anti-aligned



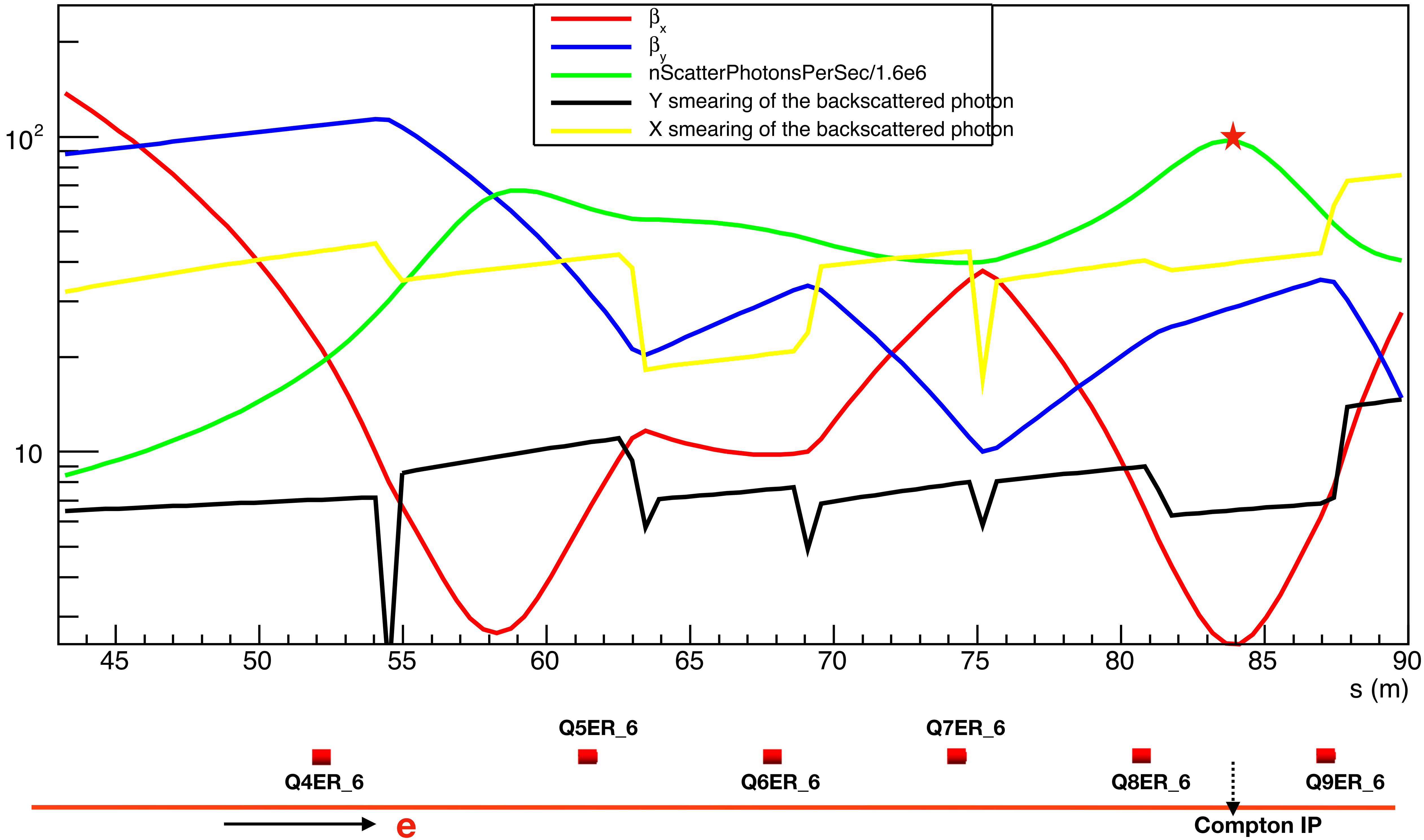


Electron detector positons

IR6 layout

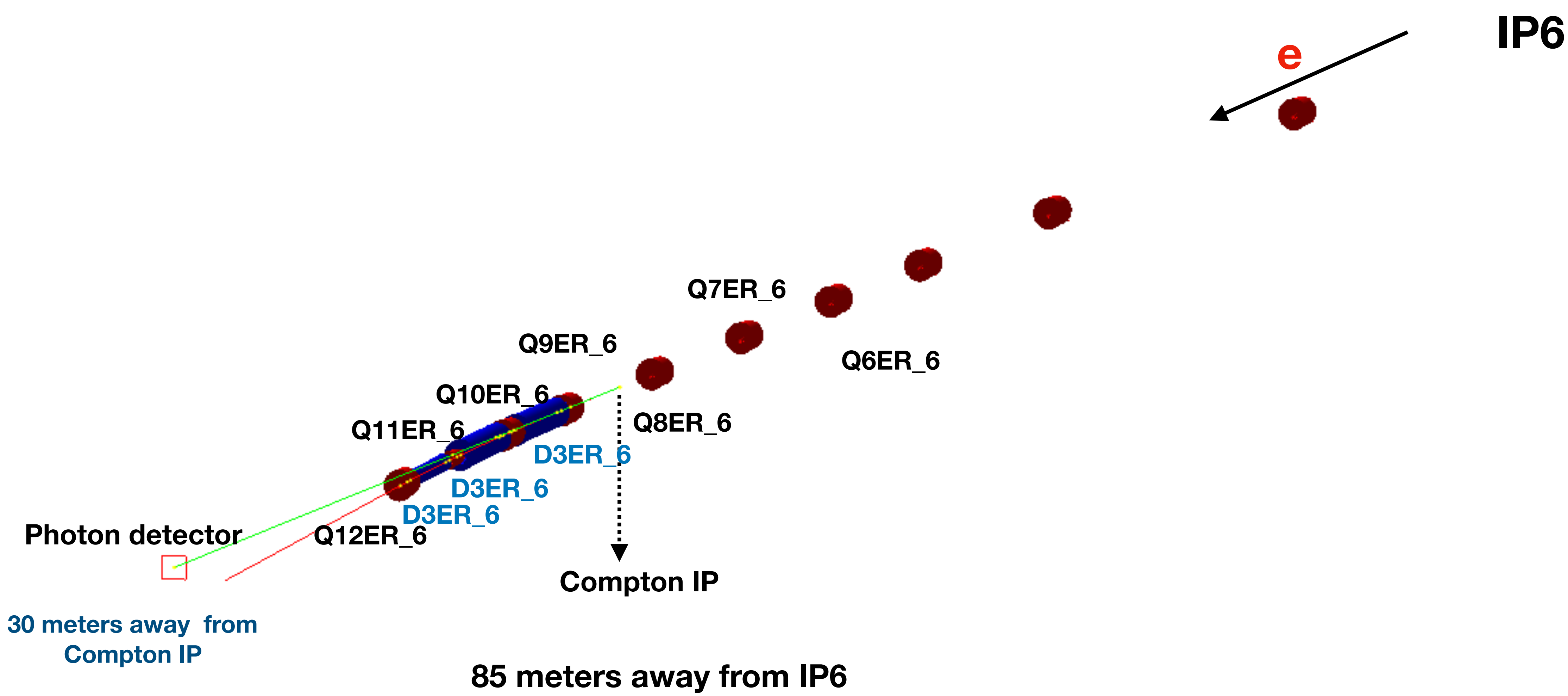

H-Dipole: Red
E-Dipole: Green
Quadrupole: Blue
Sextupole: Grey
Hadron
electrons
X
Spin components:
L: 0.7327
T: 0.6807
Compton IP
-170 m
Z
159 m
7 o'clock
6 o'clock
5 o'clock

IP6 Rear



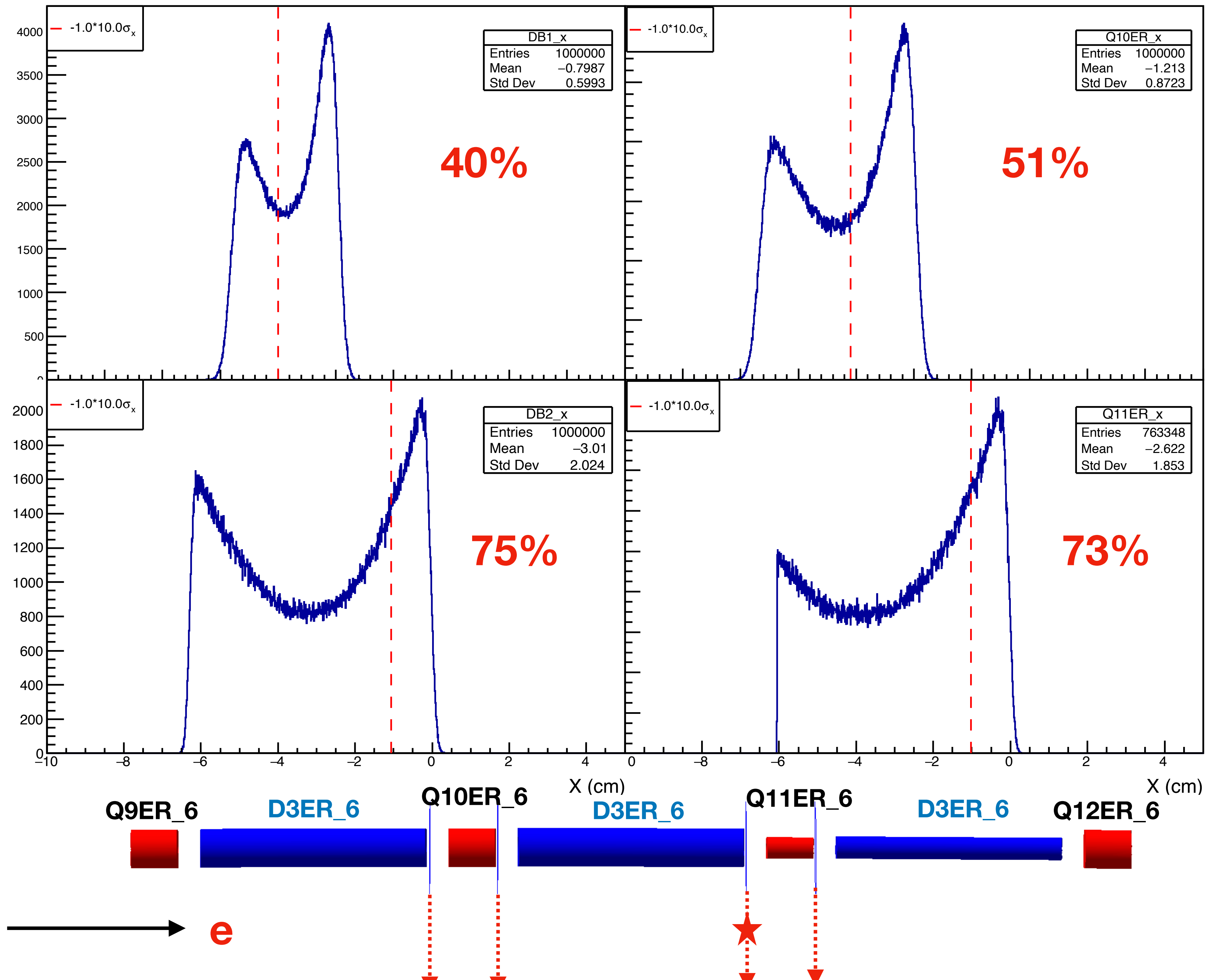
β_x
β_y
nScatterPhotonsPerSec/1.6e6
Y smearing of the backscattered photon
X smearing of the backscattered photon
10^2
10
45
50
55
60
65
70
75
80
85
90
s (m)
Q5ER_6
Q7ER_6
Q4ER_6
Q6ER_6
Q8ER_6
Q9ER_6
e
Compton IP

IP6 Rear layout



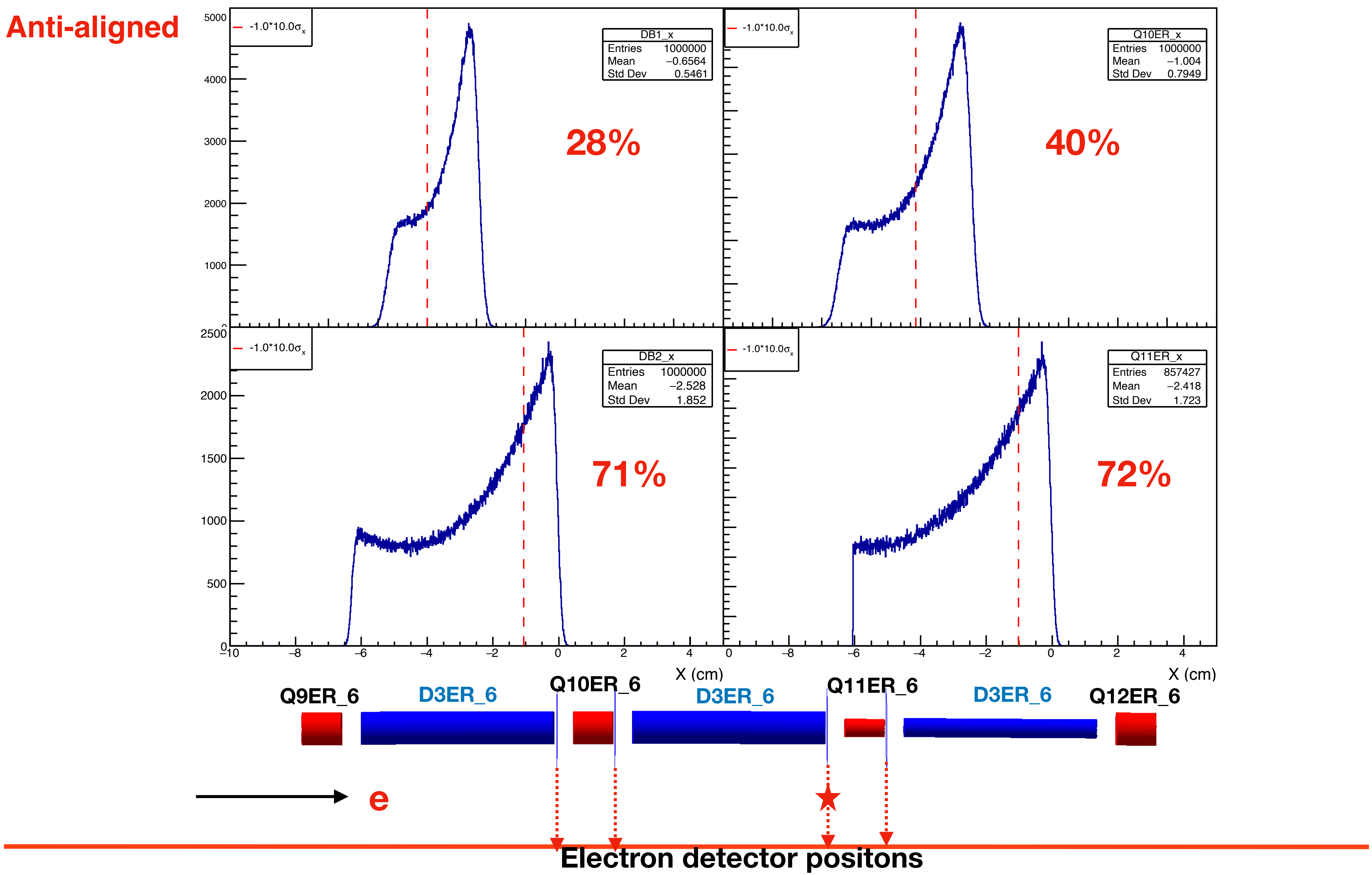
Electron detection

spins aligned



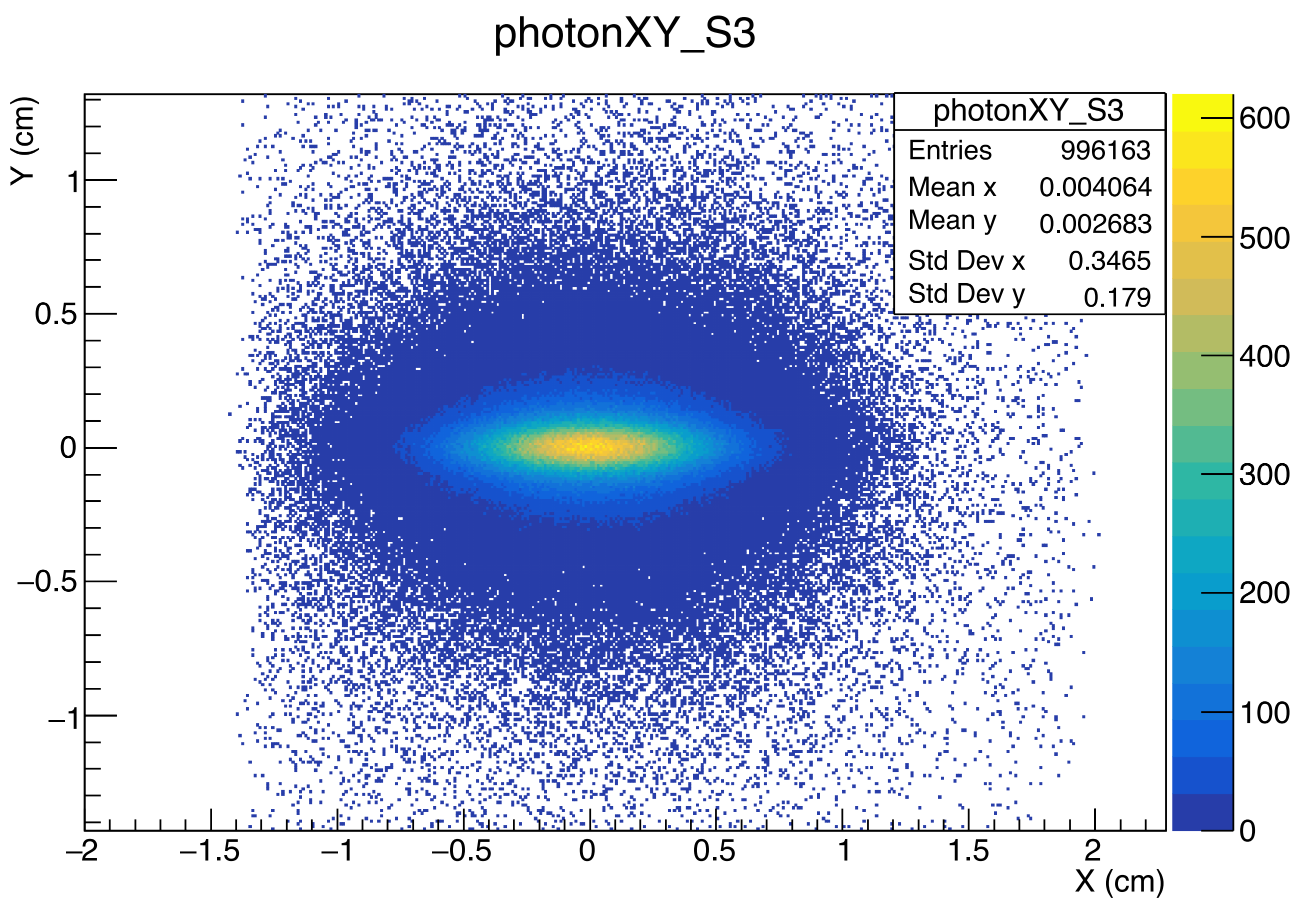
Electron detector positons

Electron detection

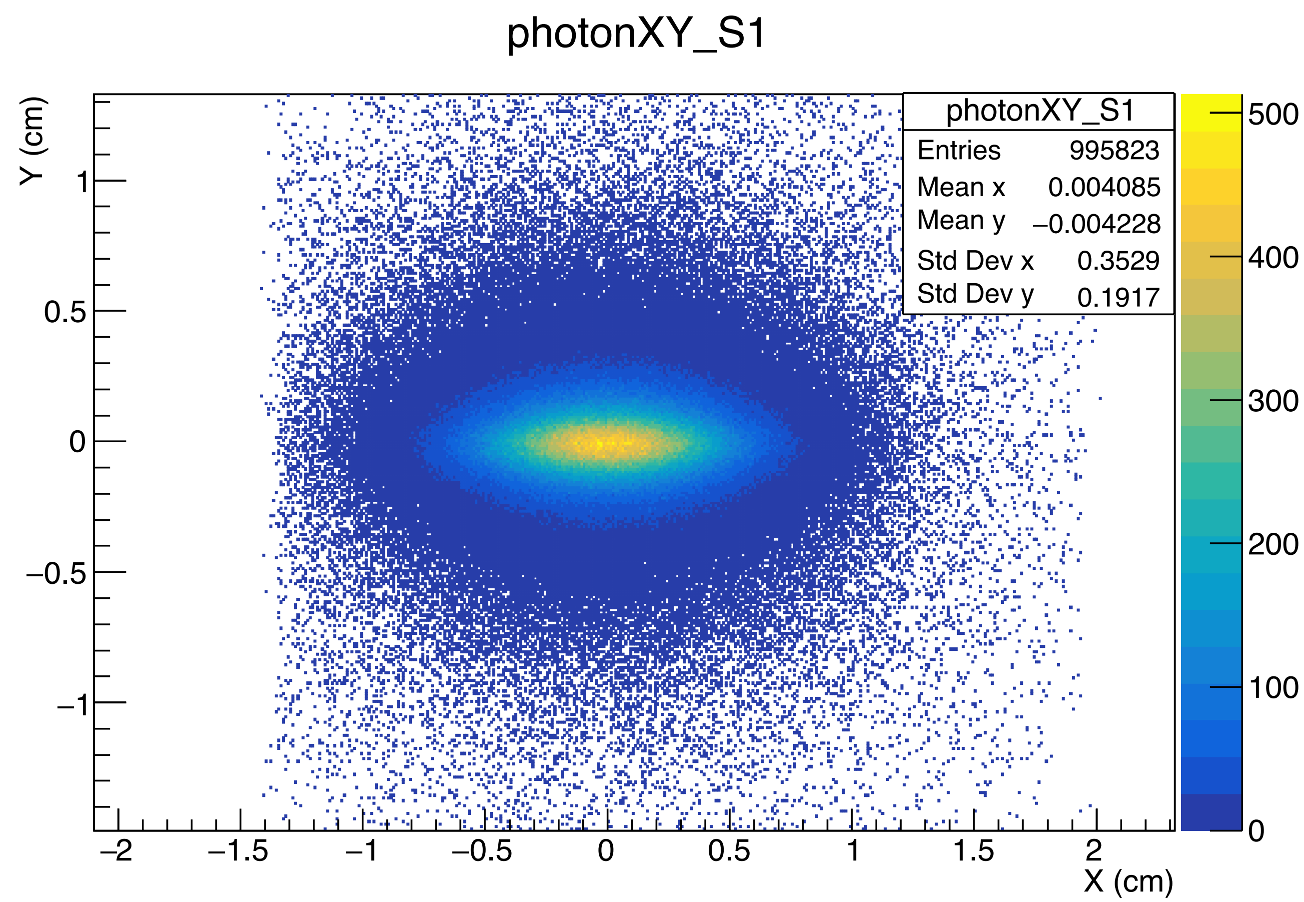


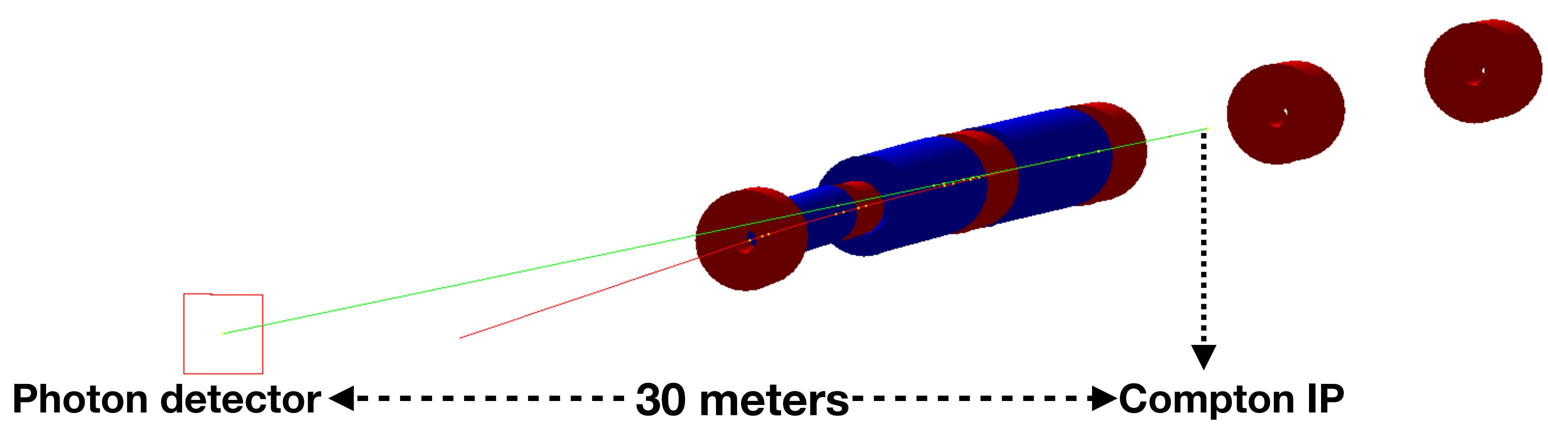
Photon detection

spins aligned

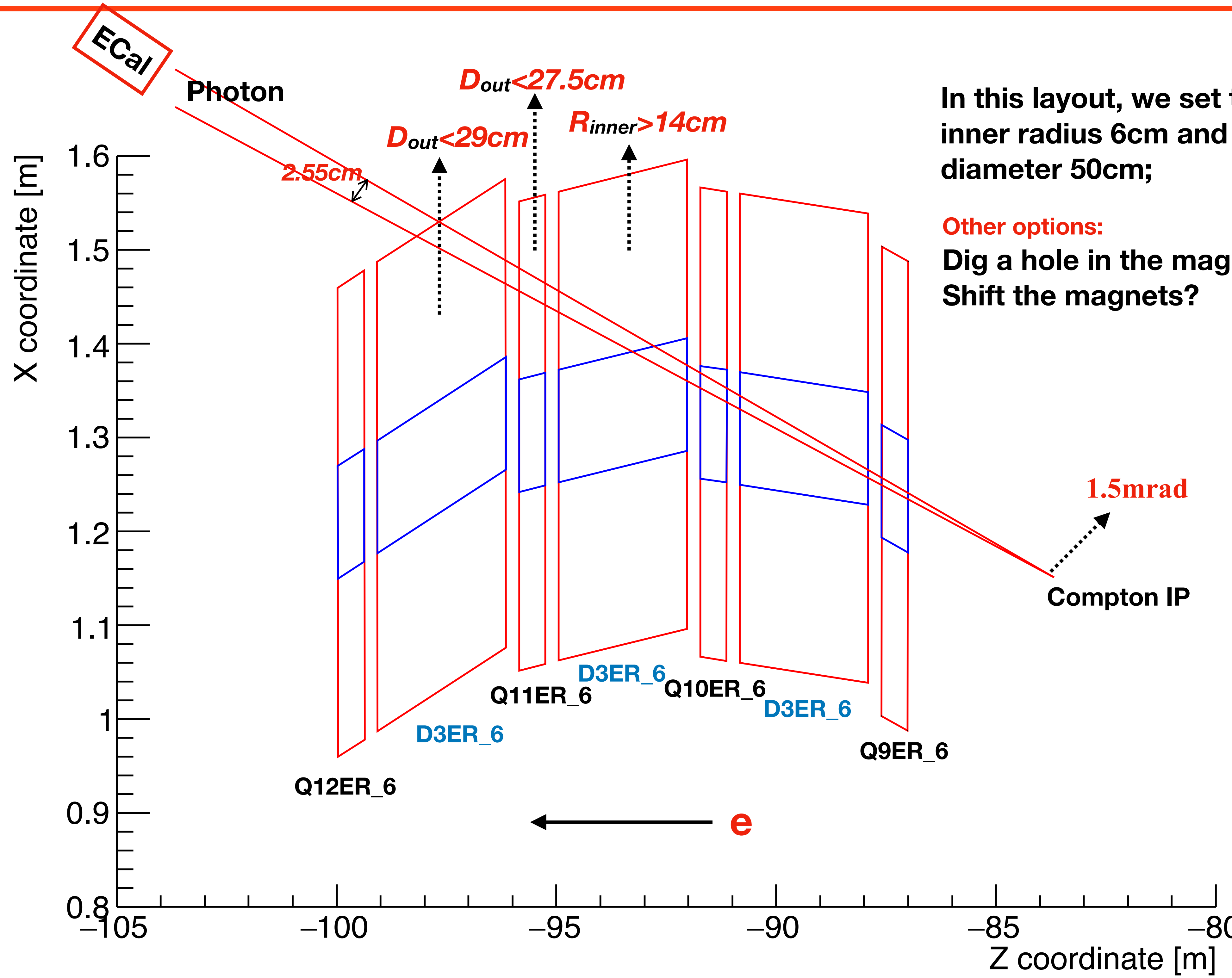


Anti-aligned





Magnets constraints in IP6 Rear



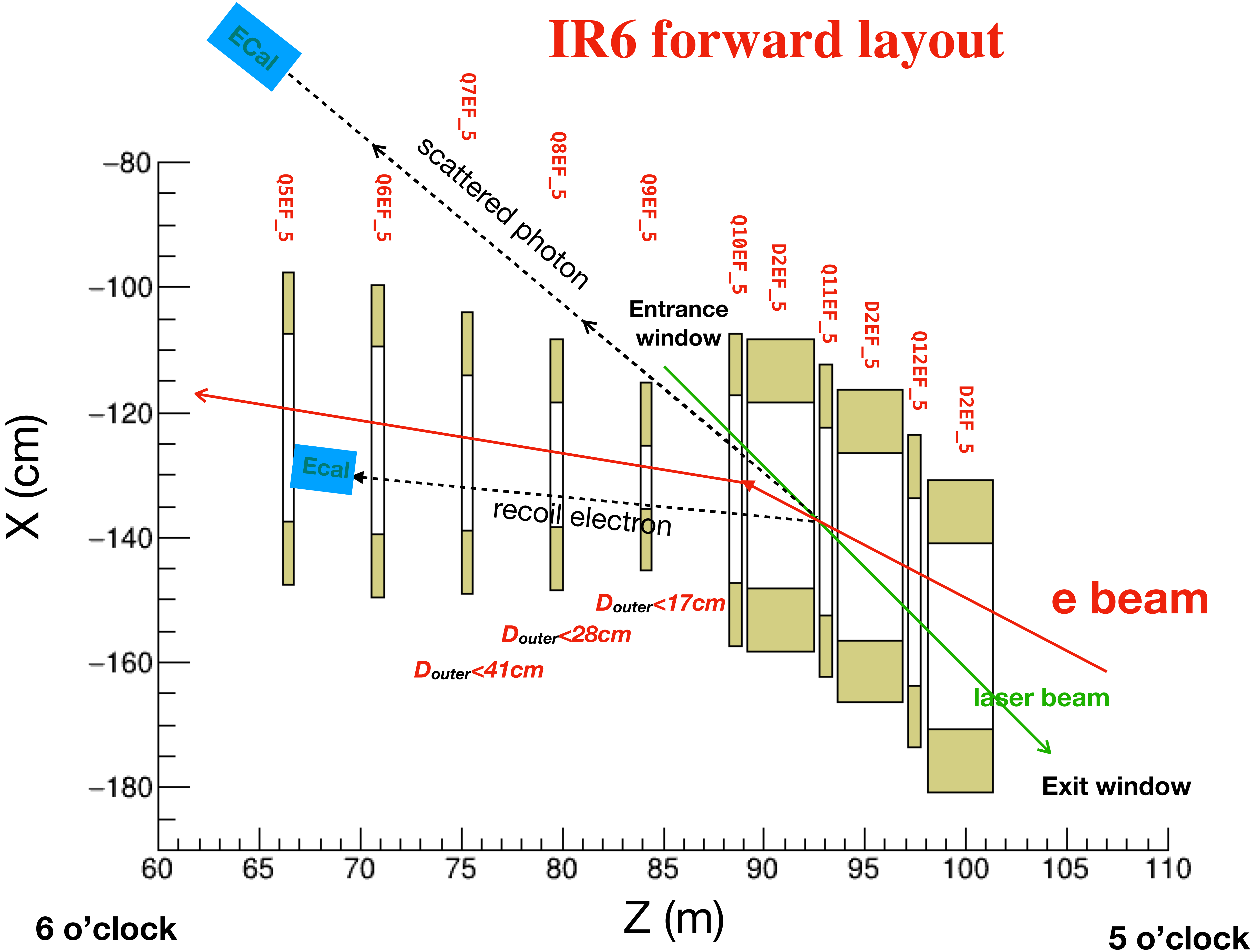
In this layout, we set the default inner radius 6cm and default diameter 50cm;

Other options:

Dig a hole in the magnets?

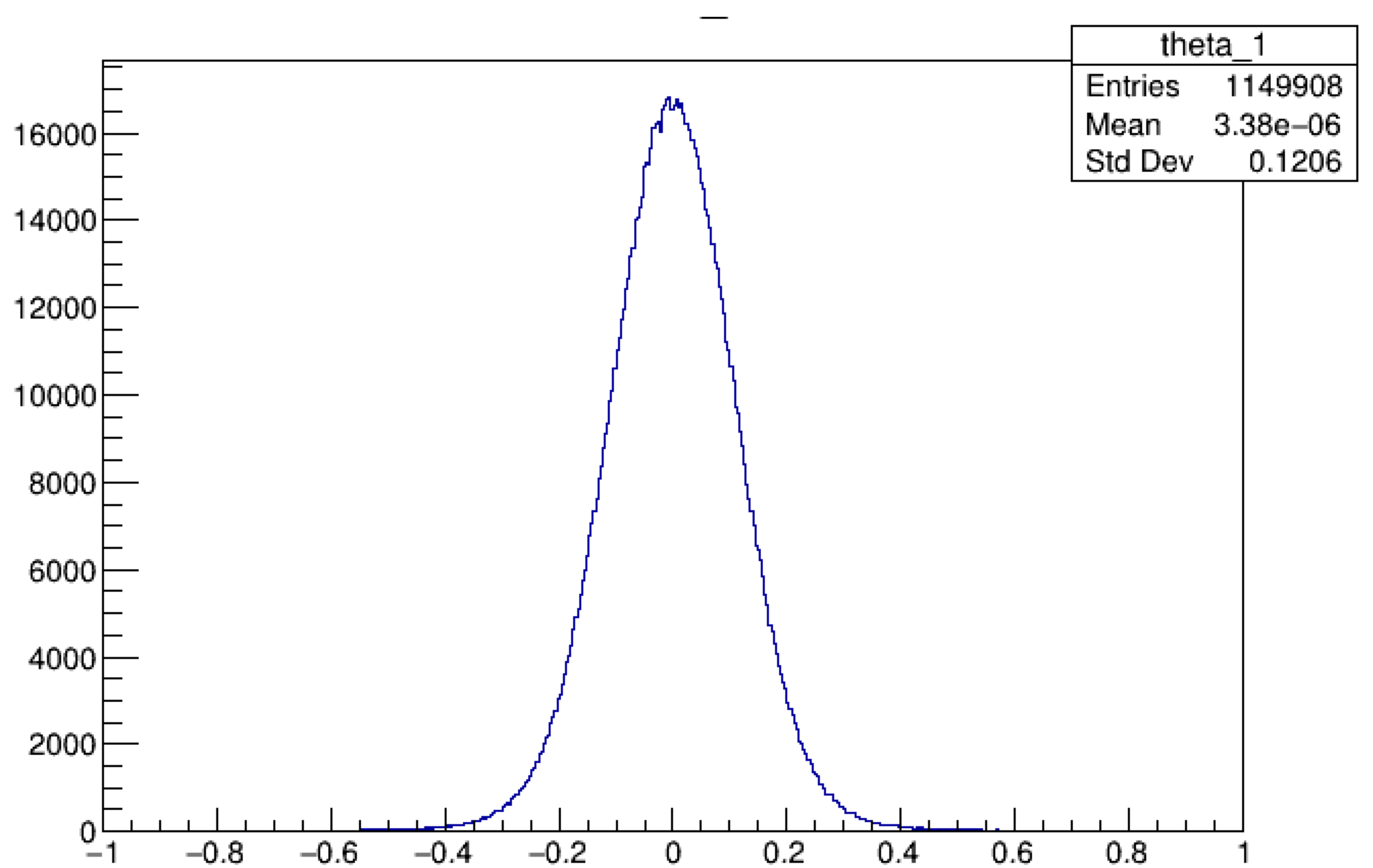
Shift the magnets?

IR6 forward layout

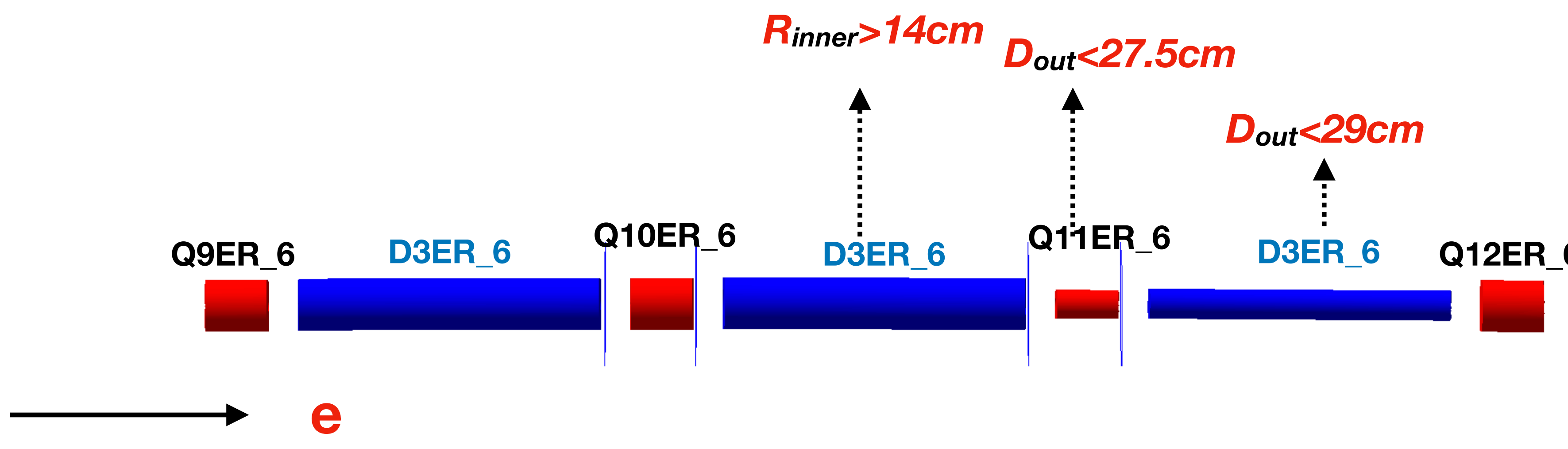


Backup

Theta distribution of scattered photon



Magnets constrain in IP6 Rear



Other options:

Studying the possibility to dig a hole in the magnets…