The Compton polarimeter in IR6

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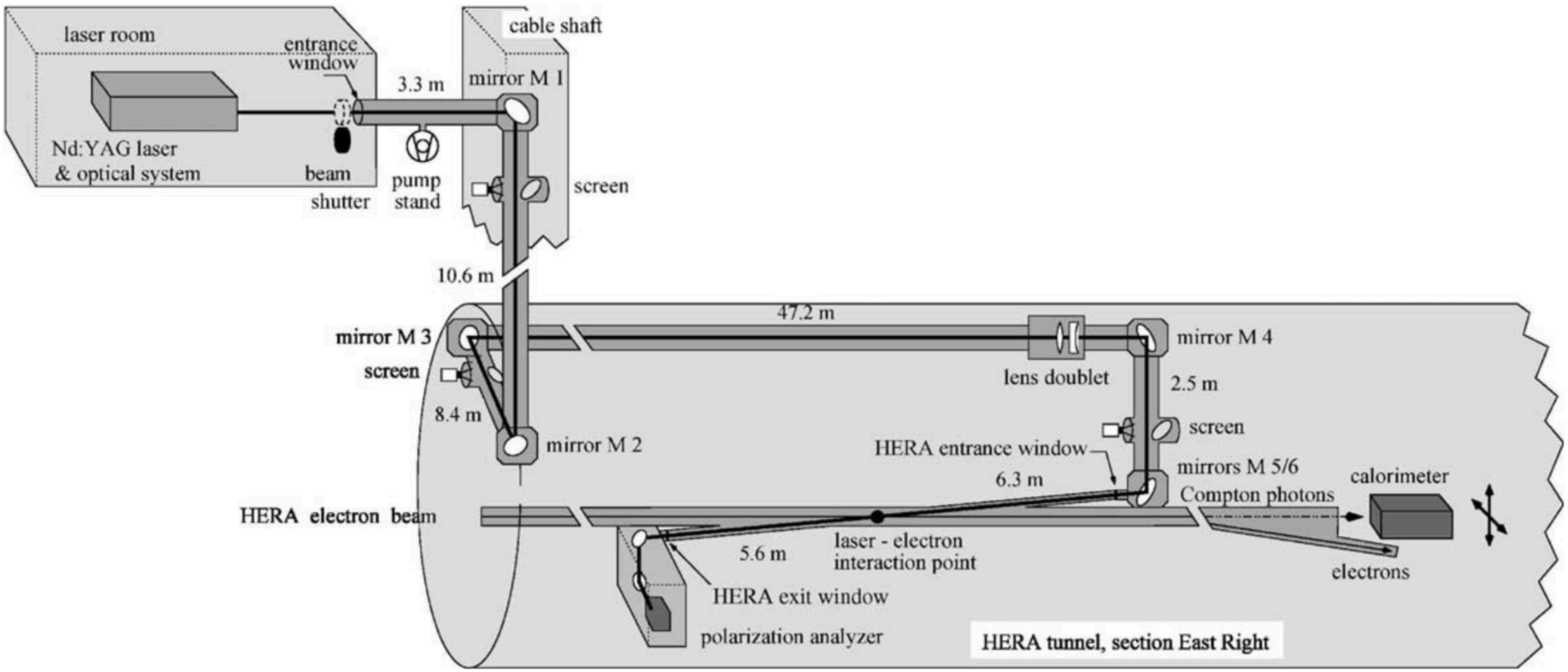
BNL

Electron polarimeter in HERA

Layout of the Longitudinal Polarimeter in the HERA East section.



Beckmann M, Borissov A, Brauksiepe S, et al. The longitudinal polarimeter at HERA[J]. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 2002, 479(2-3): 334-348.

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

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

For Quadrupole:

If K>0
$$C(s) = \cos(\sqrt{K}s),$$
$$S(s) = \frac{1}{\sqrt{K}}\sin(\sqrt{K}s),$$

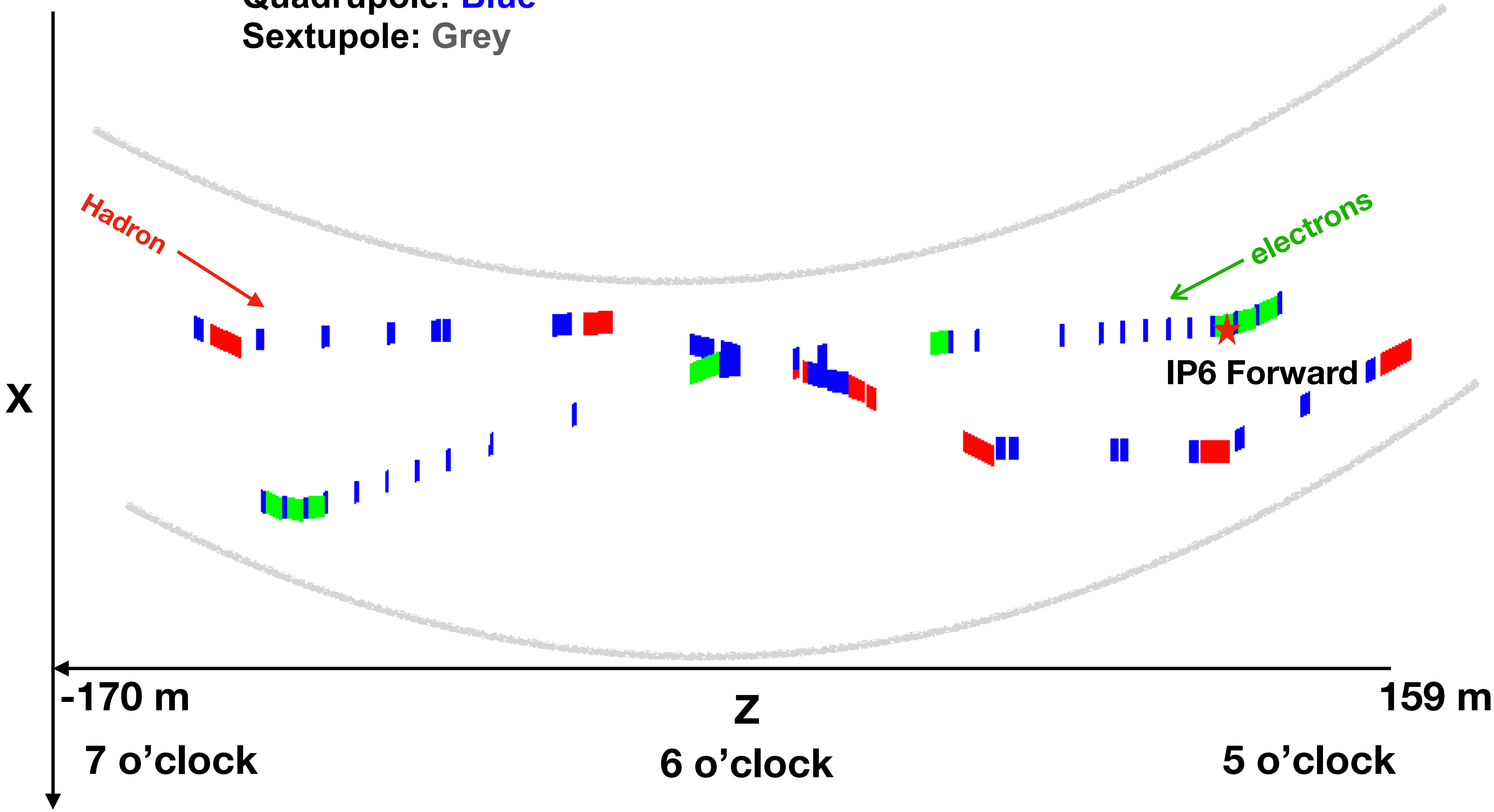
If K<0
$$C(s) = \cosh(\sqrt{K}s),$$
$$S(s) = \frac{1}{\sqrt{K}}\sinh(\sqrt{K}s)$$

$\Rightarrow$

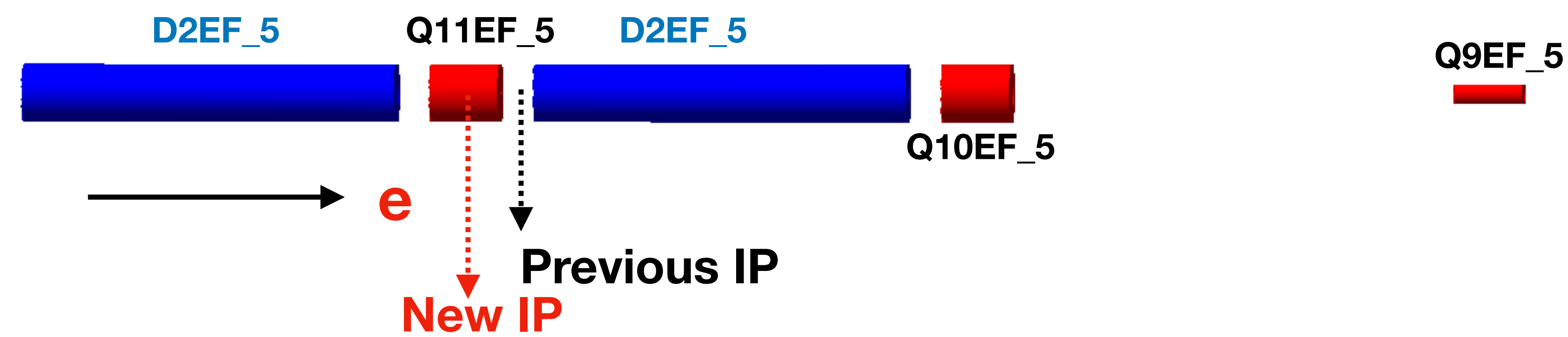
$$\beta(s) = C^2\beta_0 - 2CS\alpha_0 + S^2\gamma_0$$
$$\alpha(s) = -CC'\beta_0 + (SC' + S'C)\alpha_0 - SS'\gamma_0$$
$$\gamma(s) = C'^2\beta_0 - 2S'C'\alpha_0 + S'^2\gamma_0$$

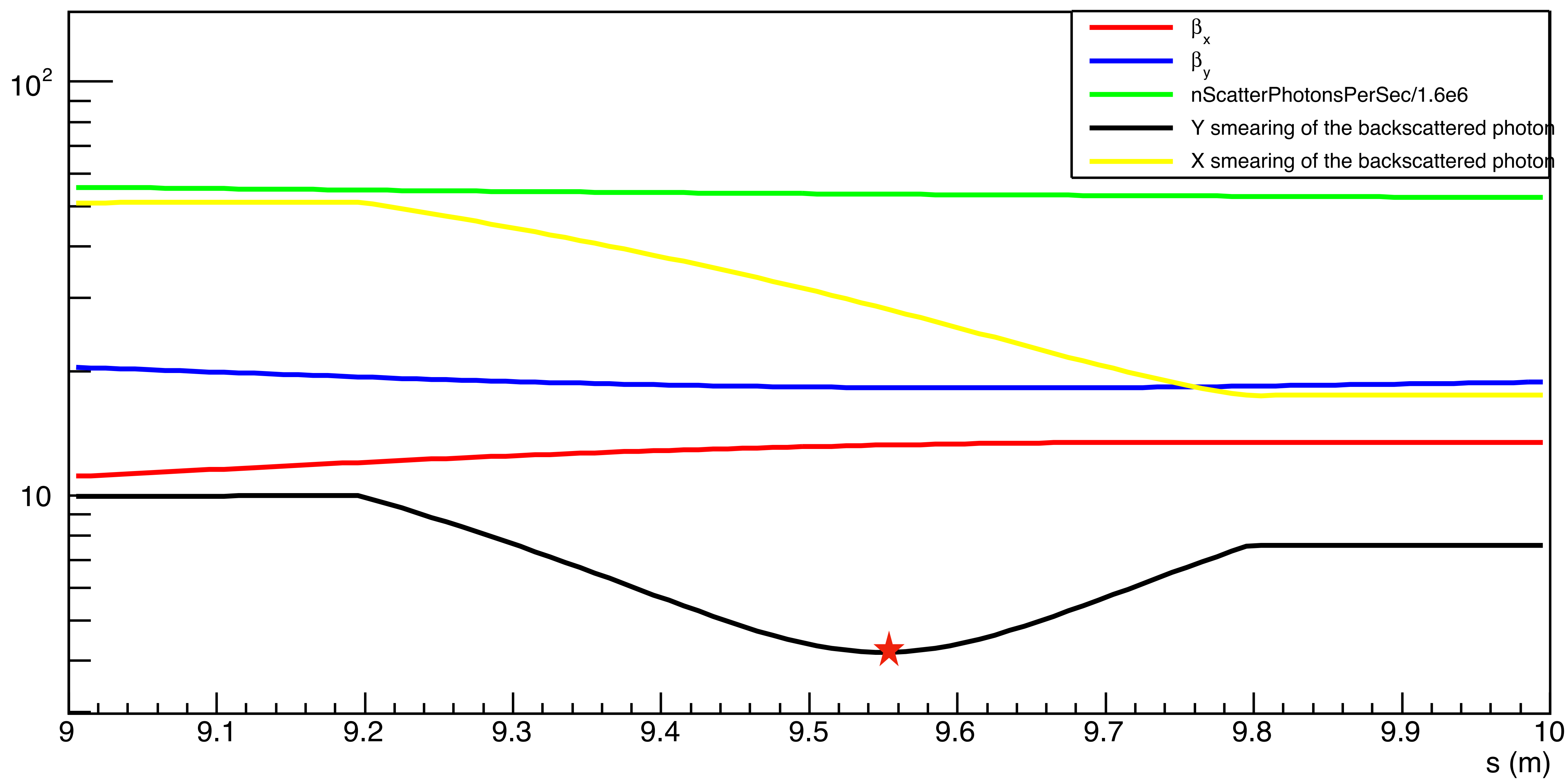
IR6 layout

H-Dipole: Red
E-Dipole: Green
Quadrupole: Blue
Sextupole: Grey

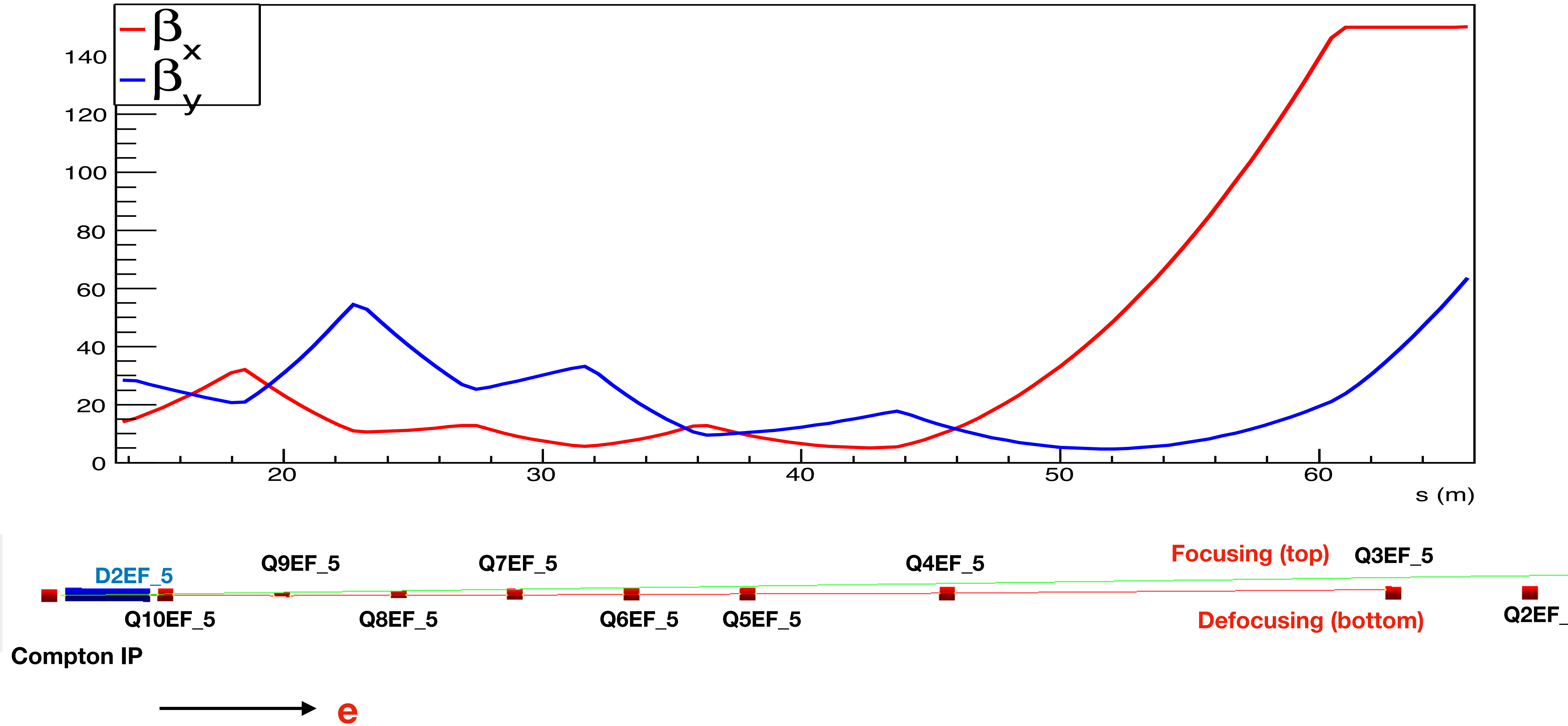


Optimize IP6 Forward Compton IP



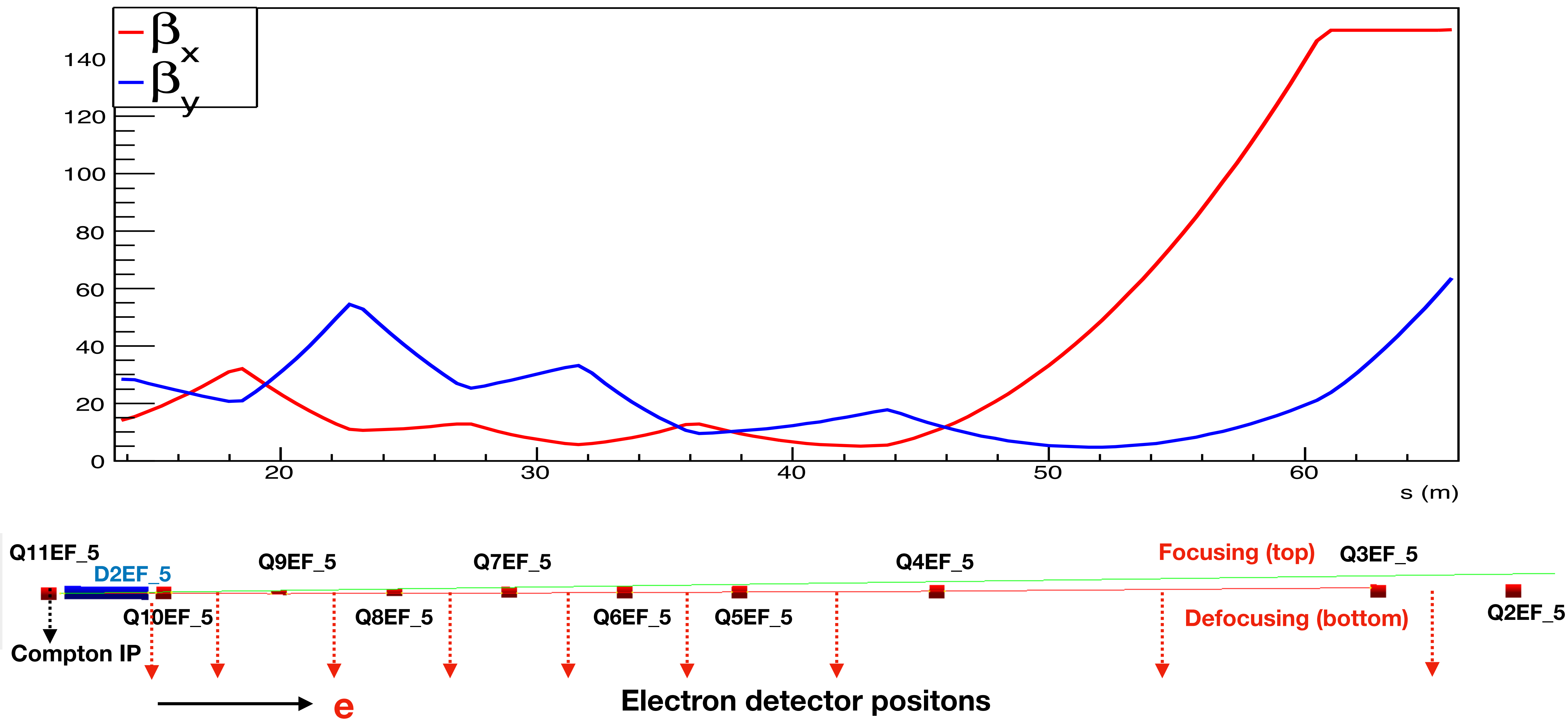


IP6 Forward

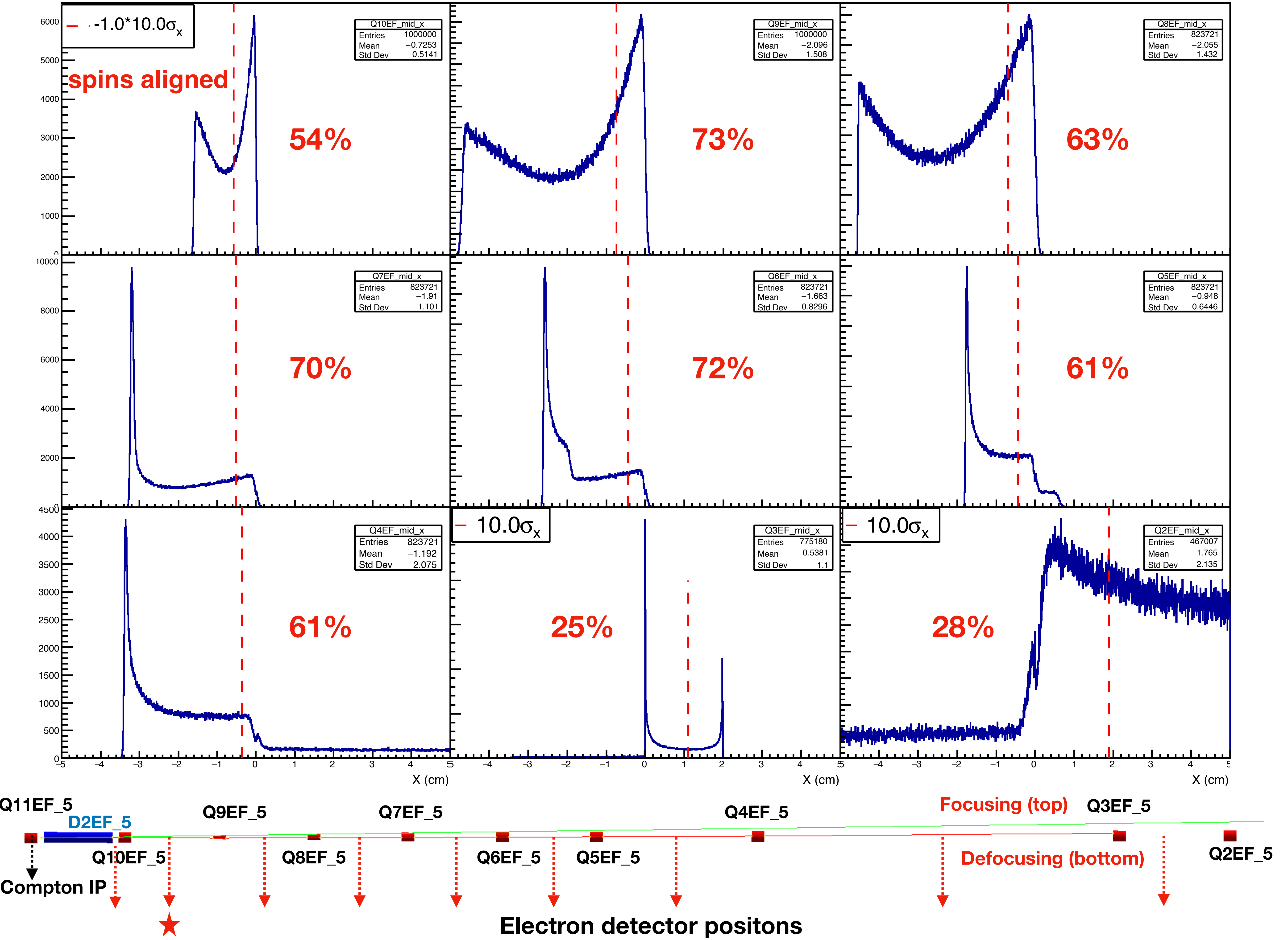


βx
βy
140
120
100
80
60
40
20
0
20
30
40
50
60
s (m)
D2EF_5
Q9EF_5
Q7EF_5
Q4EF_5
Focusing (top)
Q3EF_5
Q10EF_5
Q8EF_5
Q6EF_5
Q5EF_5
Defocusing (bottom)
Q2EF_5
Compton IP
e

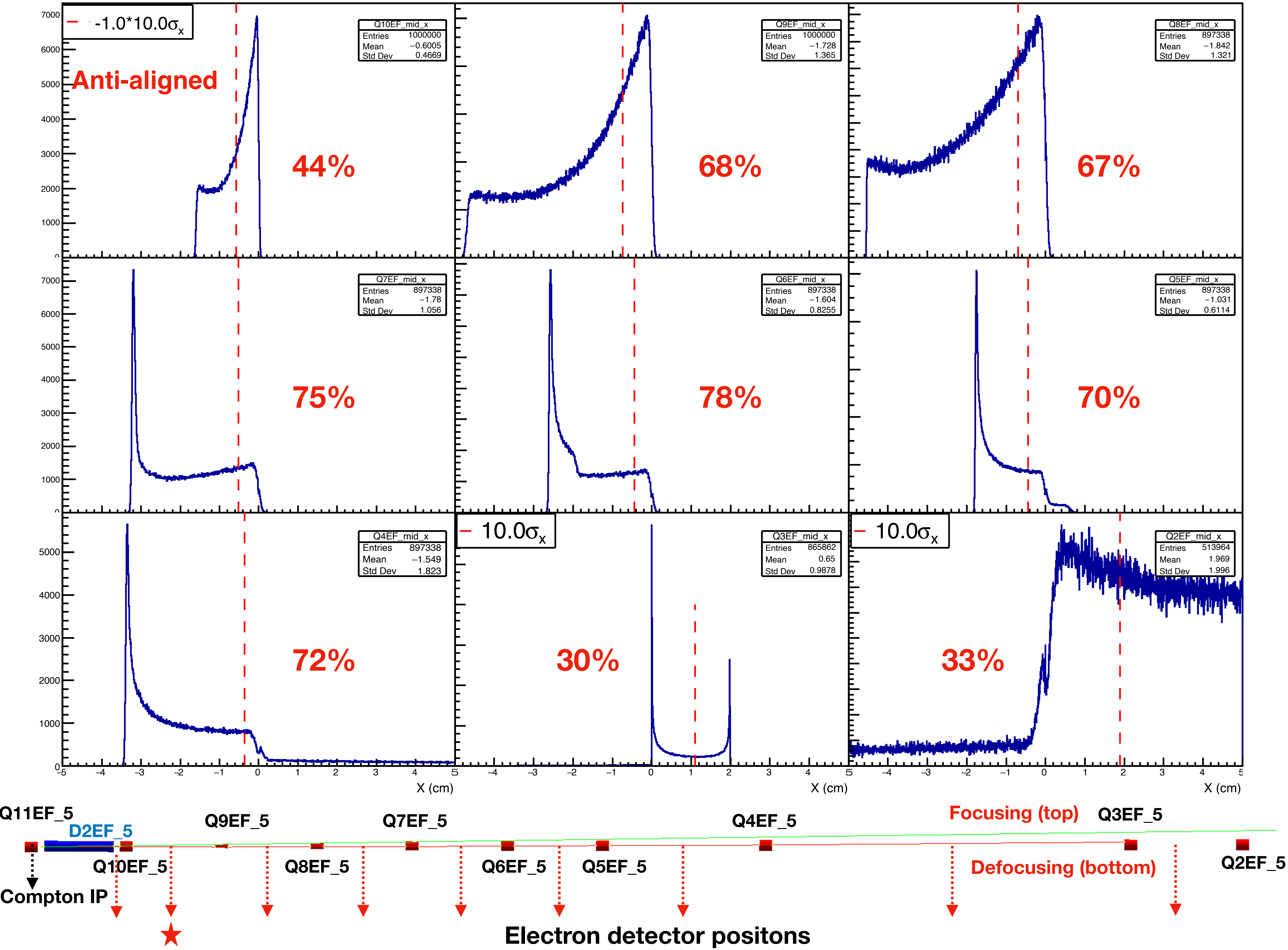
IP6 Forward



βx
βy
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



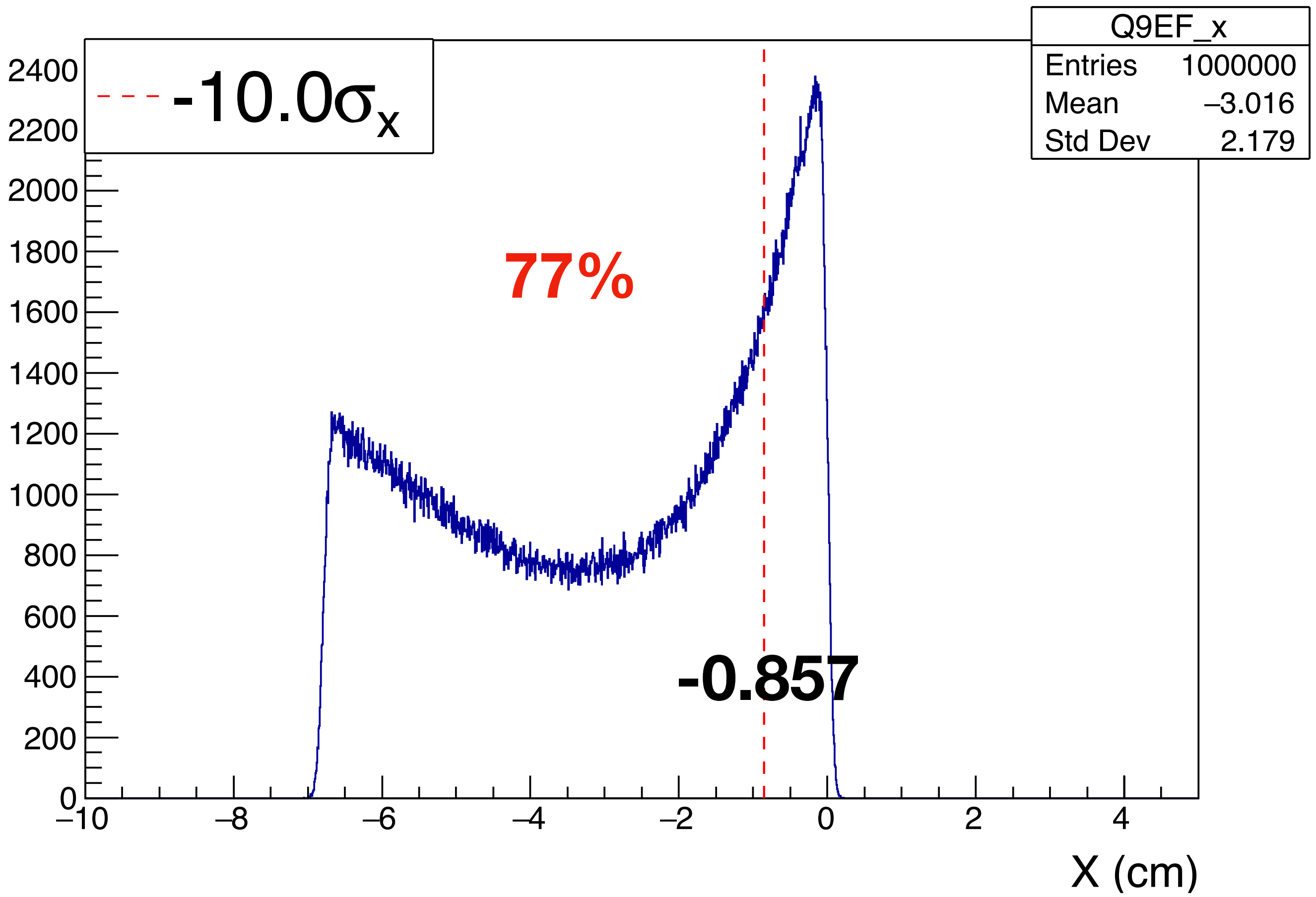
-1.0*10.0σx
spins aligned
Q10EF_mid_x
Entries 1000000
Mean −0.7253
Std Dev 0.5141
54%
Q9EF_mid_x
Entries 1000000
Mean −2.096
Std Dev 1.508
73%
Q8EF_mid_x
Entries 823721
Mean −2.055
Std Dev 1.432
63%
Q7EF_mid_x
Entries 823721
Mean −1.91
Std Dev 1.101
70%
Q6EF_mid_x
Entries 823721
Mean −1.663
Std Dev 0.8296
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%
10.0σx
Q3EF_mid_x
Entries 775180
Mean 0.5381
Std Dev 1.1
25%
10.0σx
Q2EF_mid_x
Entries 467007
Mean 1.765
Std Dev 2.135
28%
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



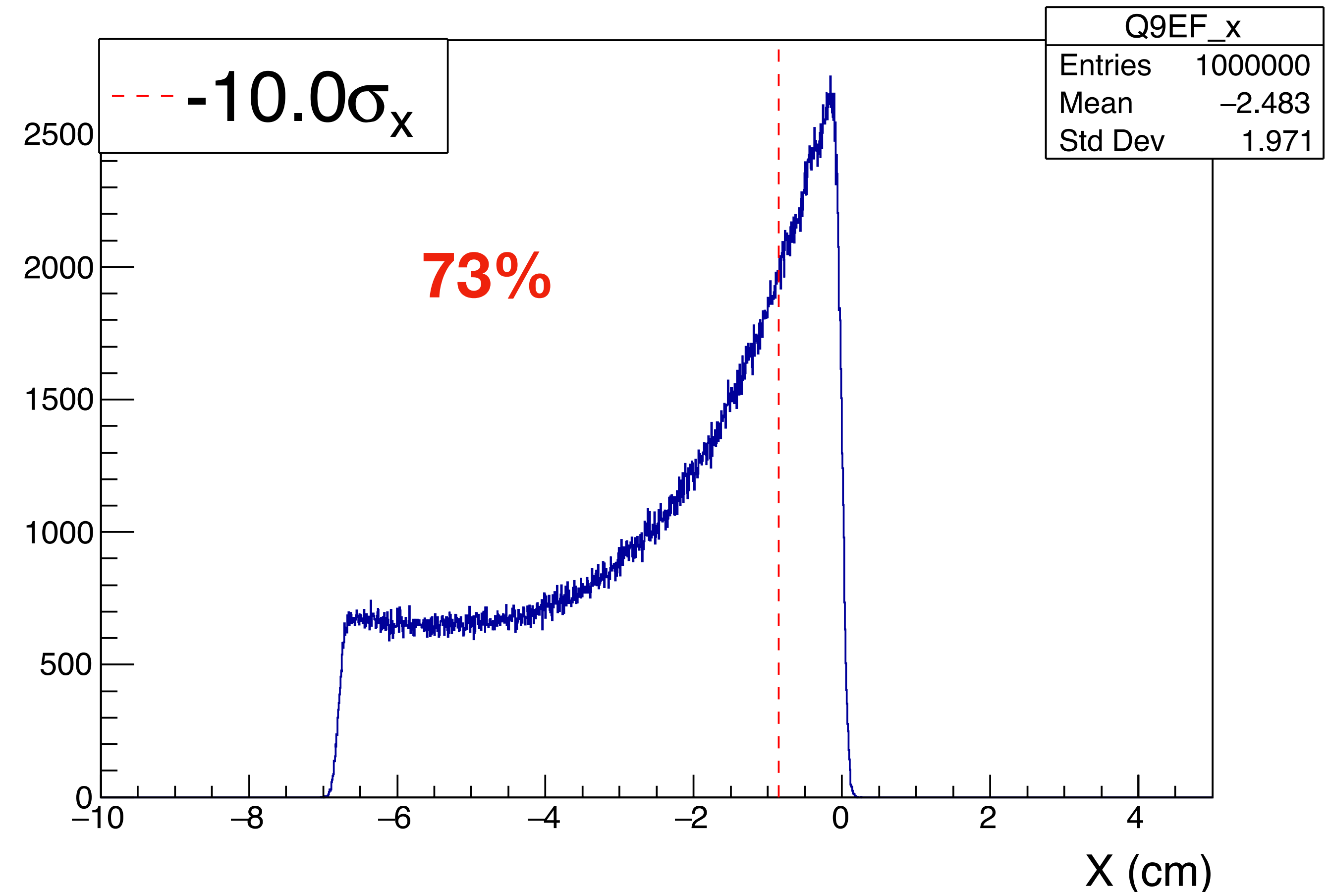
-1.0*10.0σx
Anti-aligned
Q10EF_mid_x
Entries 1000000
Mean −0.6005
Std Dev 0.4669
44%
Q9EF_mid_x
Entries 1000000
Mean −1.728
Std Dev 1.365
68%
Q8EF_mid_x
Entries 897338
Mean −1.842
Std Dev 1.321
67%
Q7EF_mid_x
Entries 897338
Mean −1.78
Std Dev 1.056
75%
Q6EF_mid_x
Entries 897338
Mean −1.604
Std Dev 0.8255
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

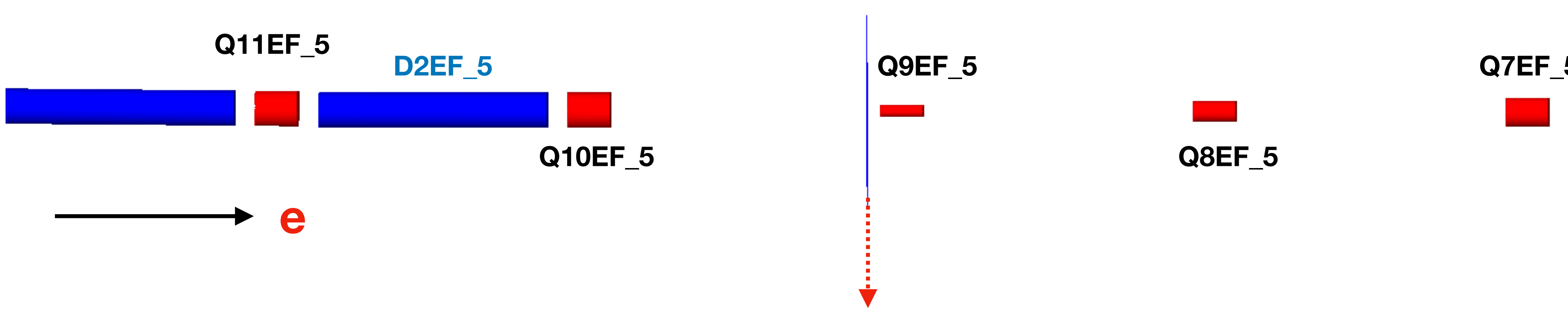
Electron detection

spins aligned



Anti-aligned

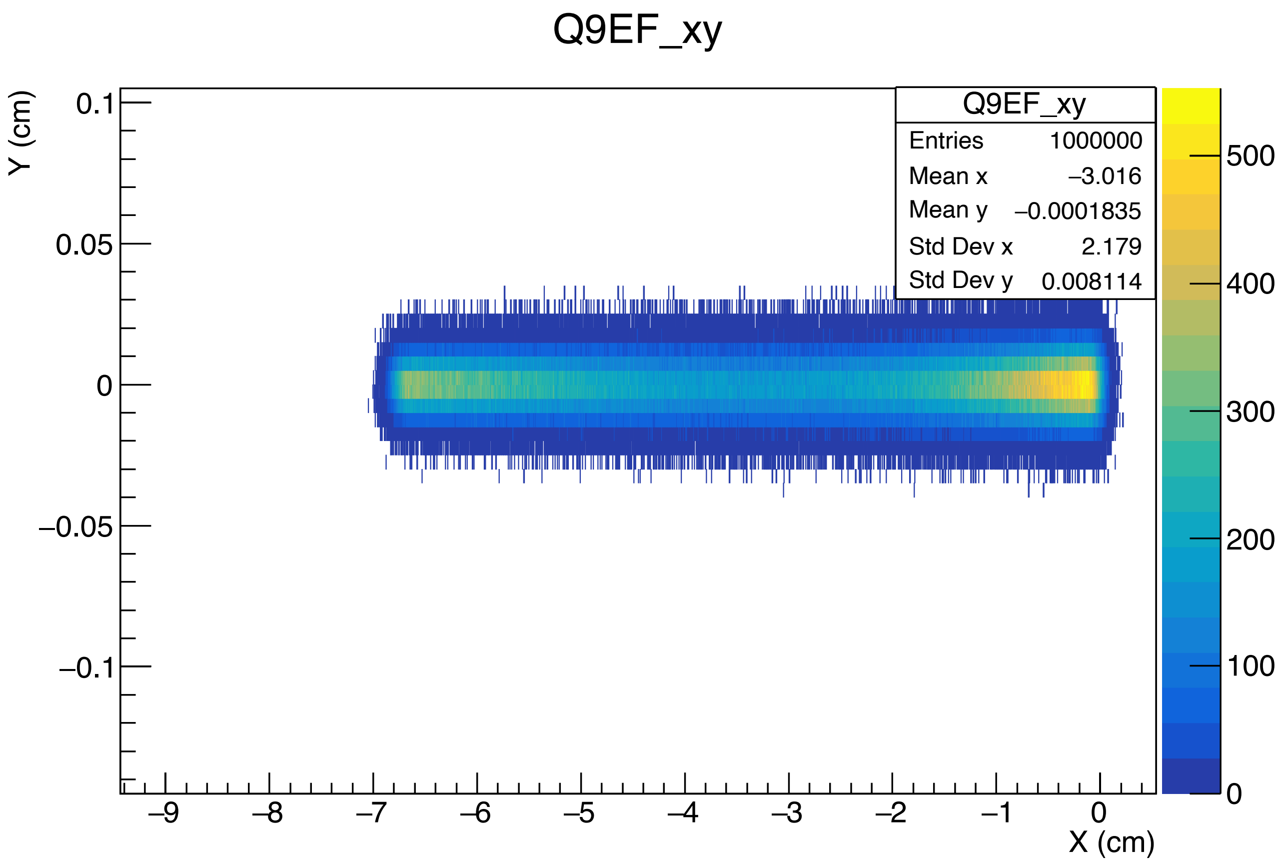




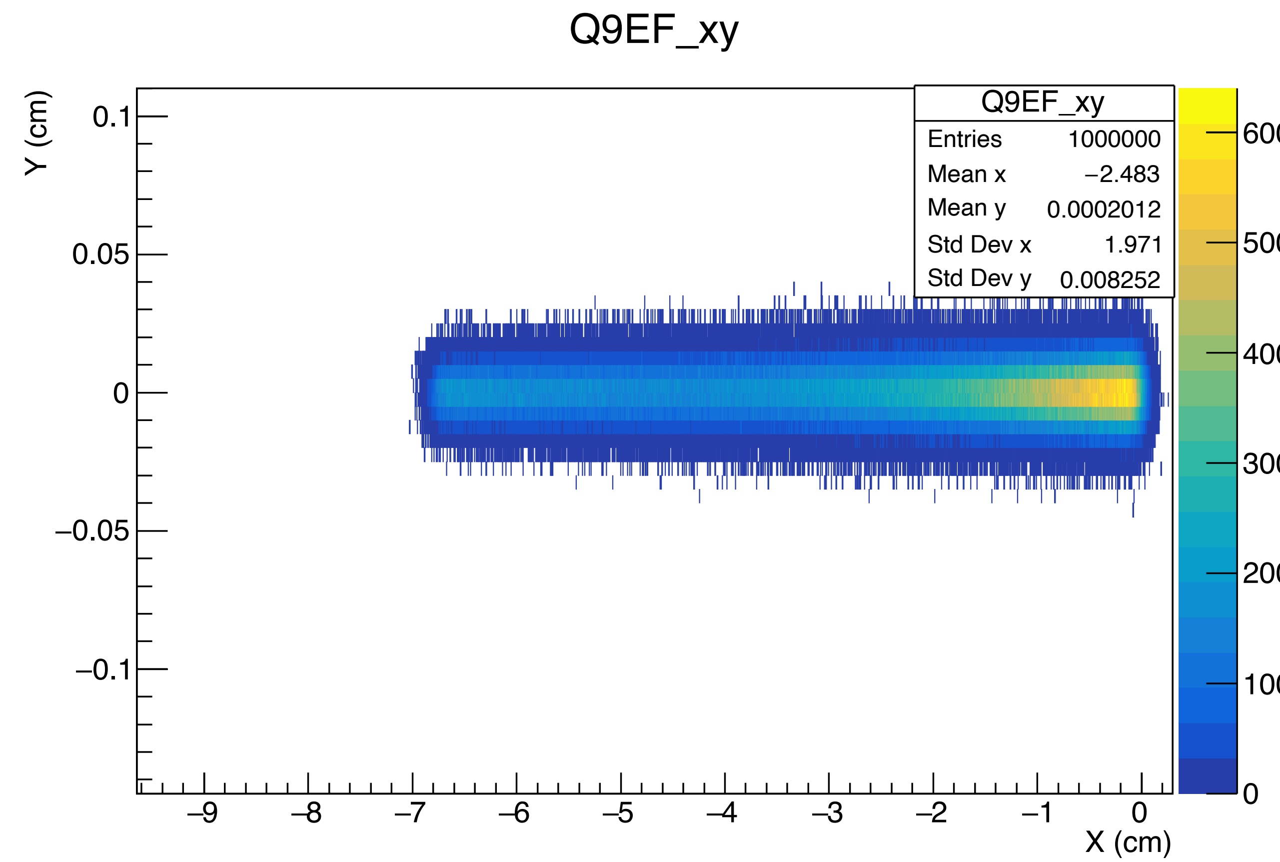
Electron detector positons

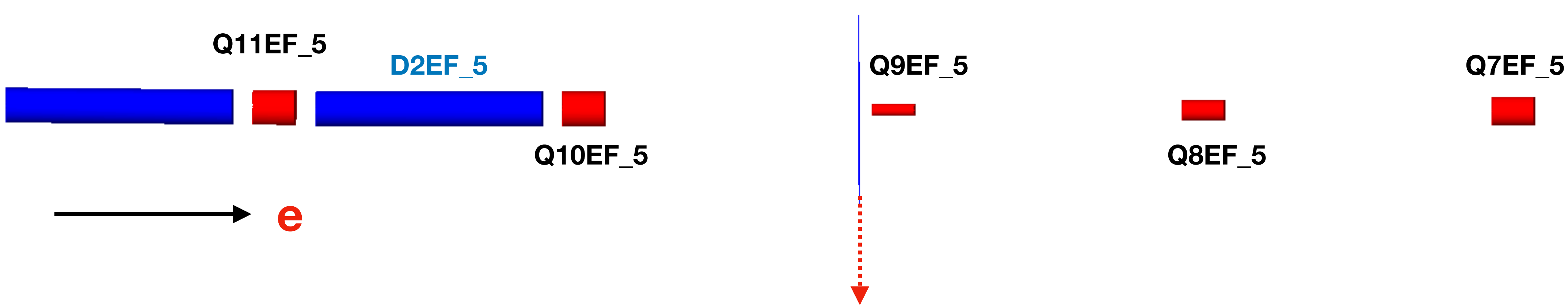
Electron detection

spins aligned



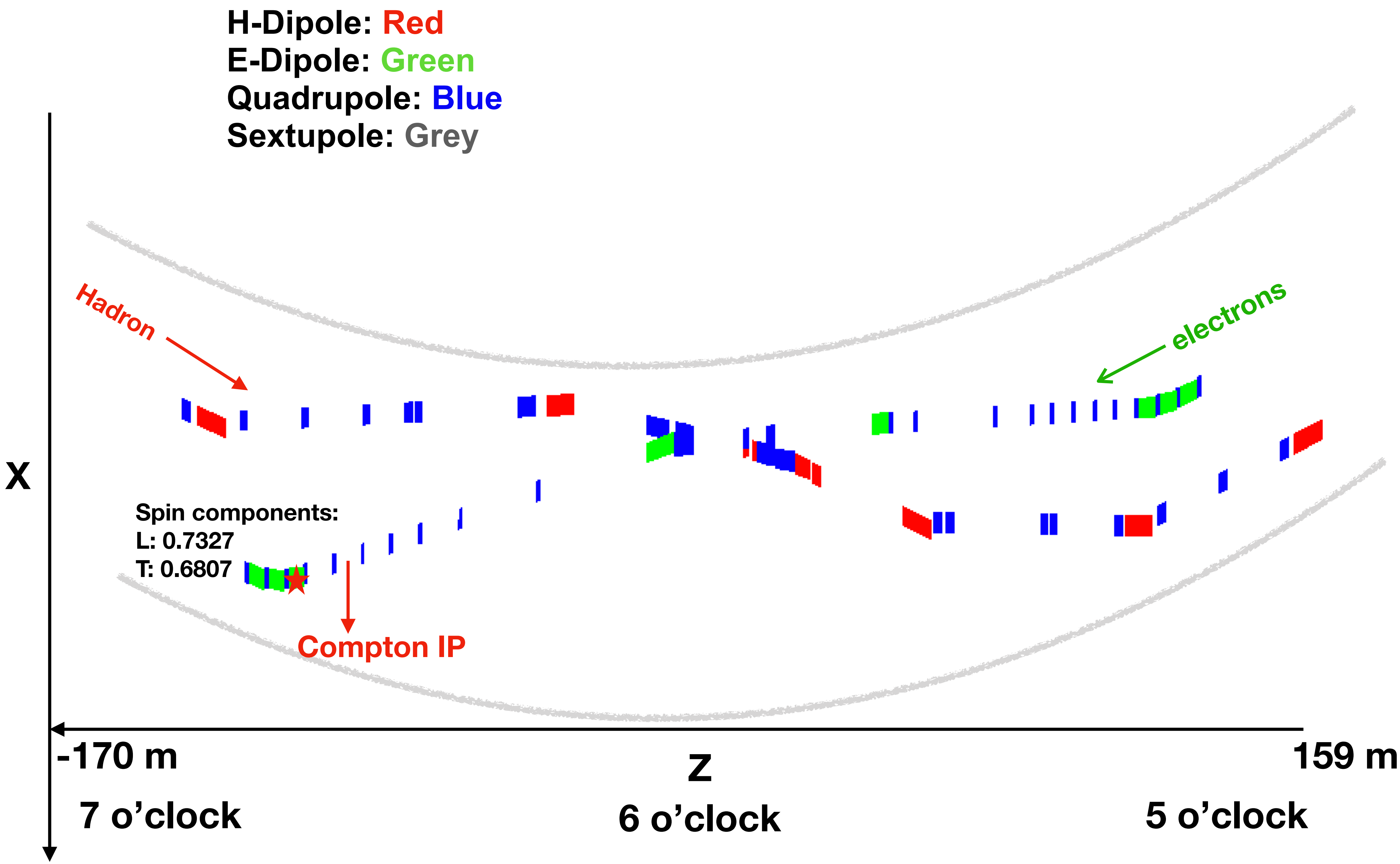
Anti-aligned



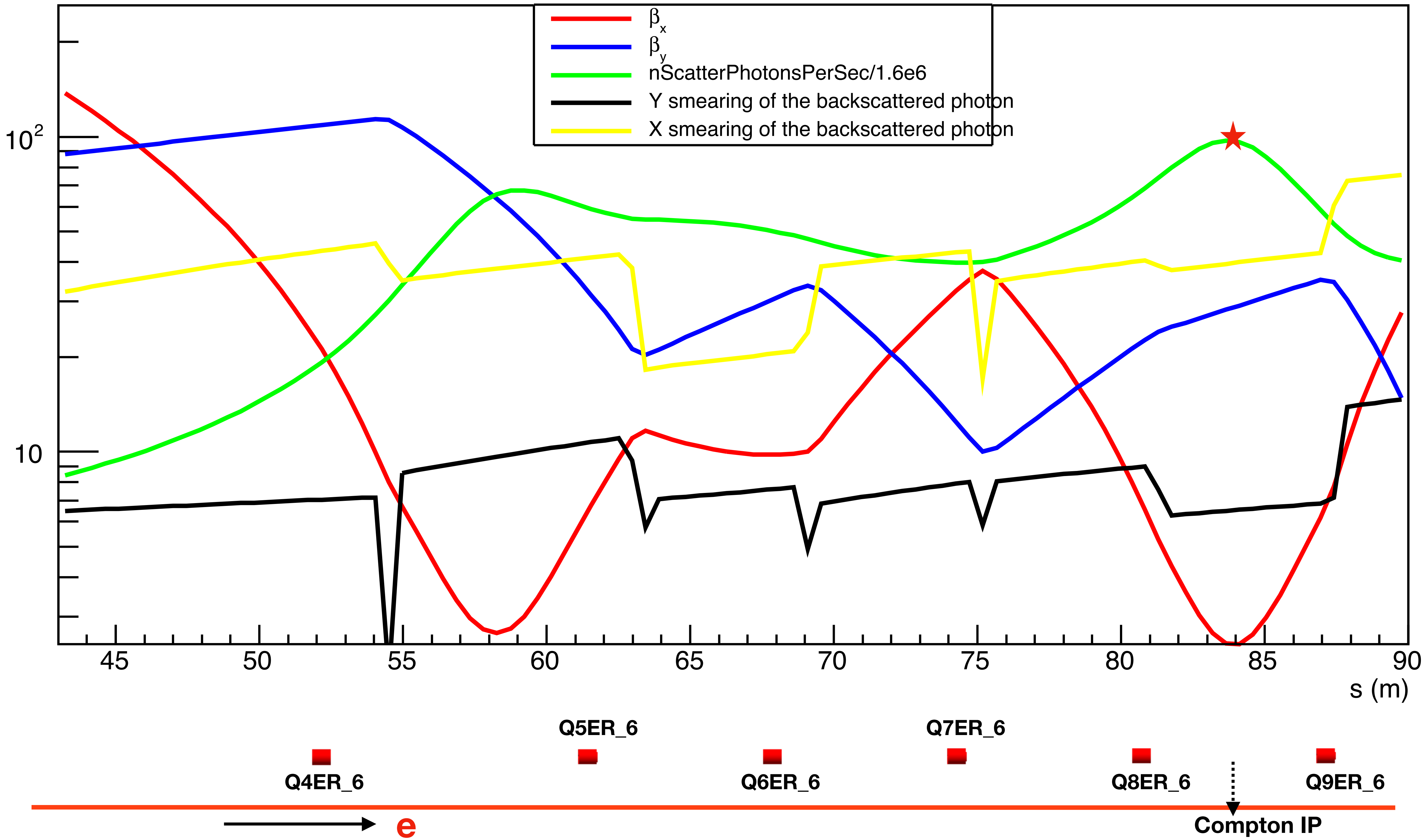


Electron detector positons

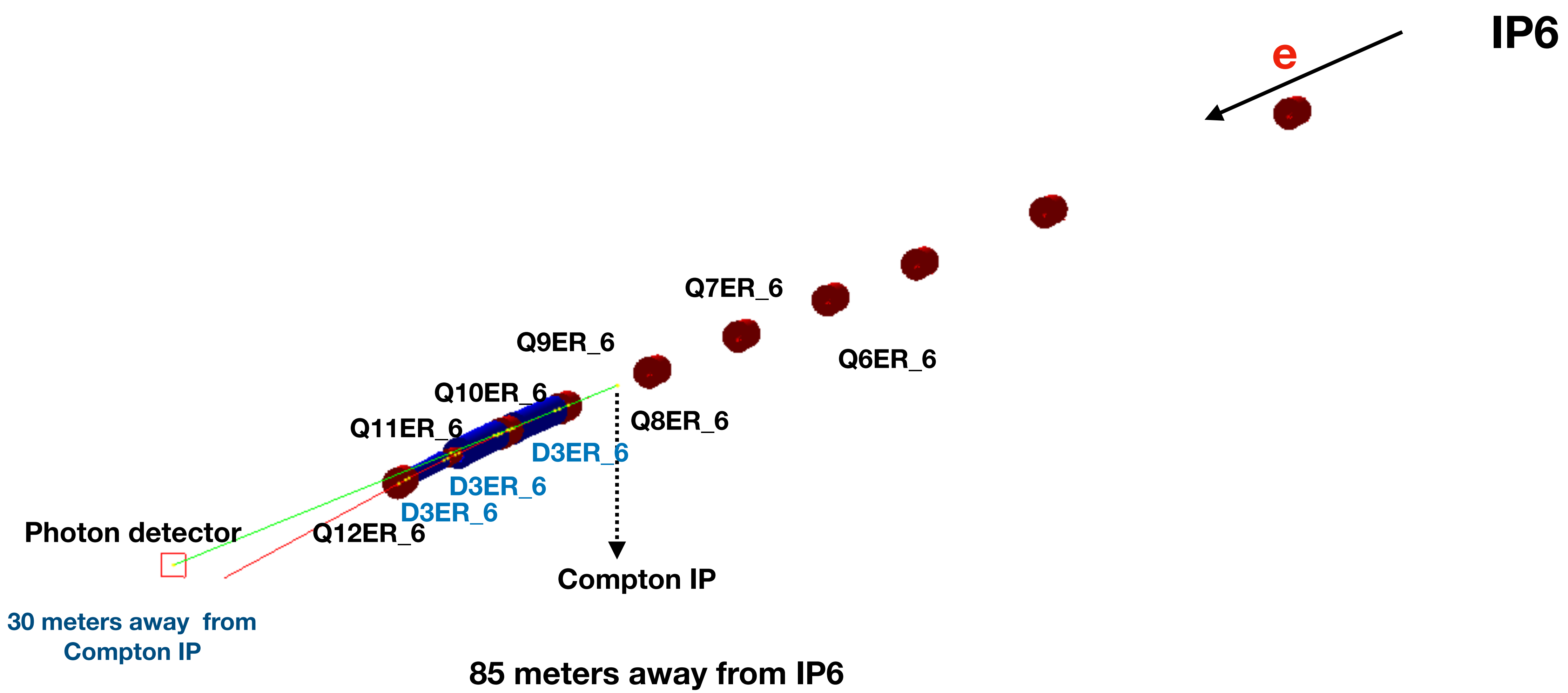
IR6 layout


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

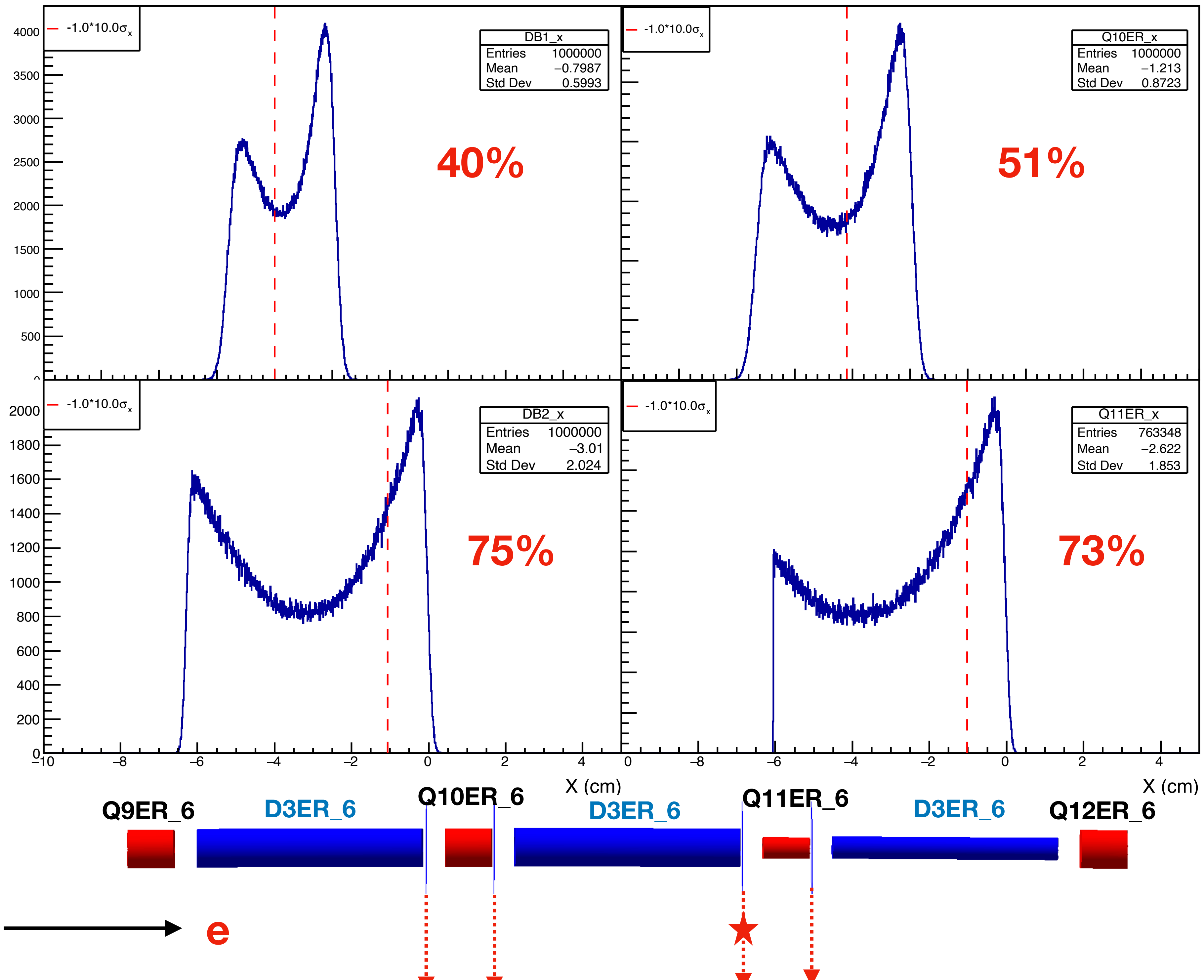

βx
βy
nScatterPhotonsPerSec/1.6e6
Y smearing of the backscattered photon
X smearing of the backscattered photon
10²
10
45
50
55
60
65
70
75
80
85
90
s (m)
Q5ER_6
Q7ER_6
Q4ER_6
Q6ER_6
Q8ER_6
Q9ER_6
e
Compton IP

IP6 Rear layout



Electron detection

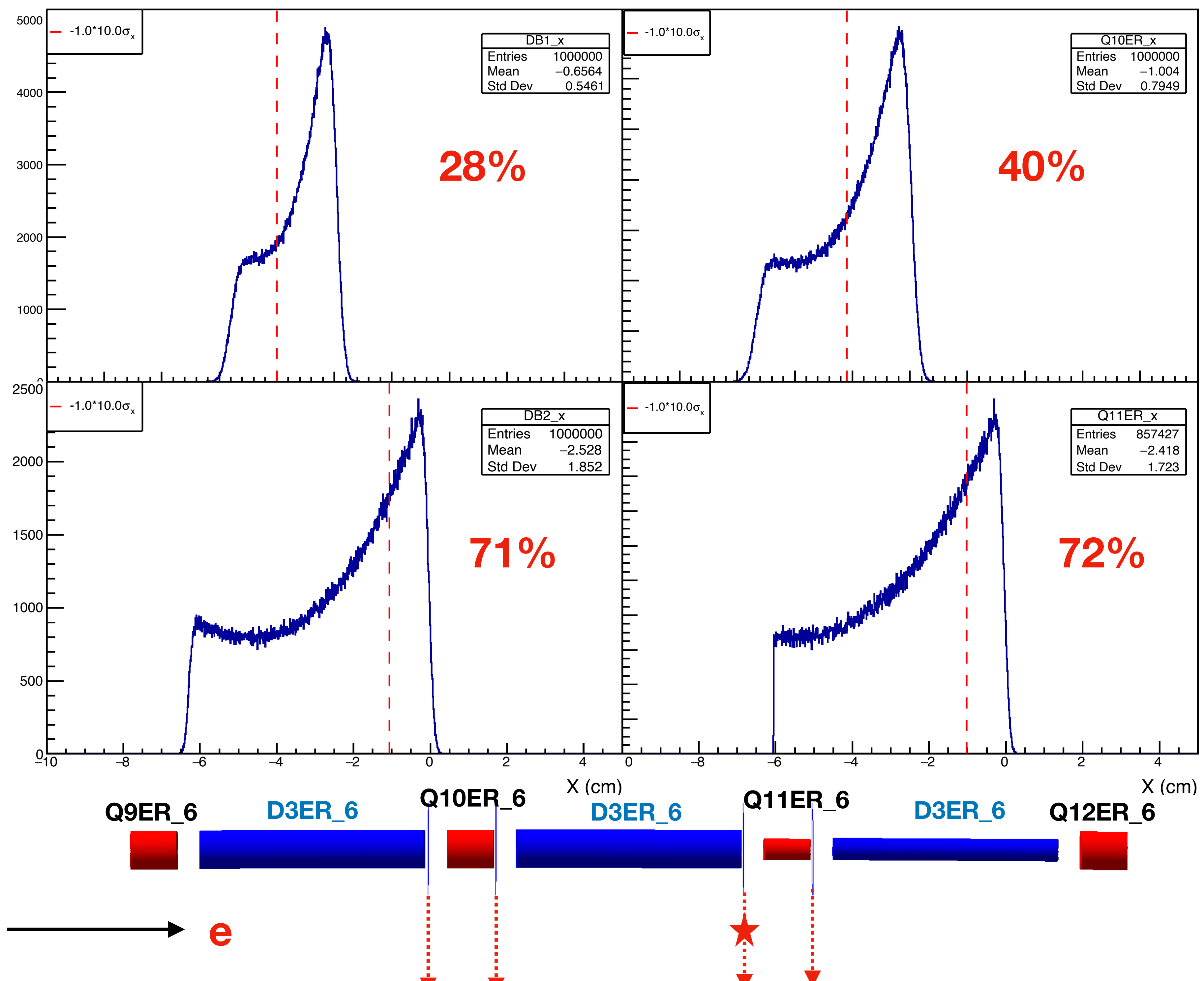
spins aligned



Electron detector positons

Electron detection

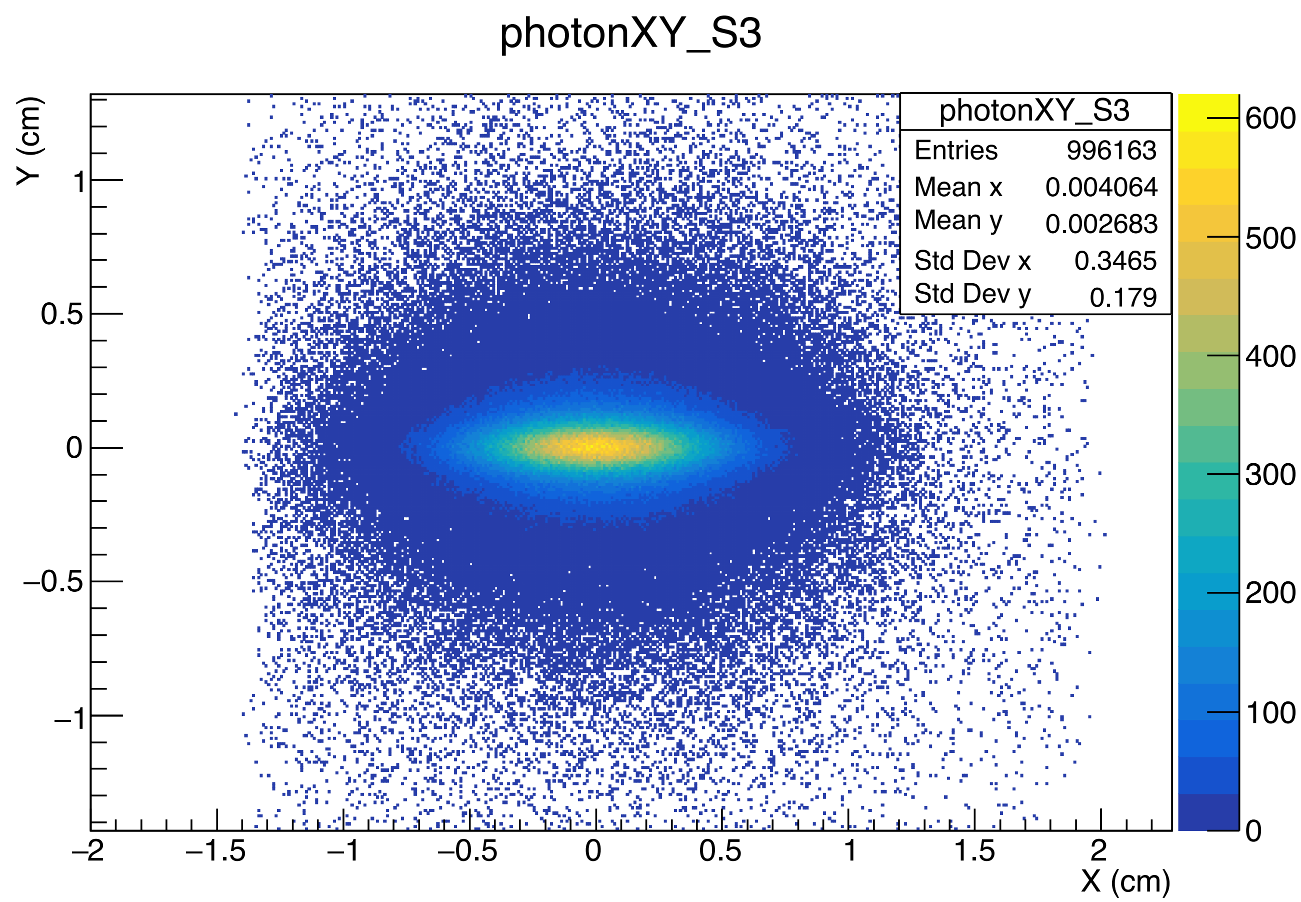
Anti-aligned



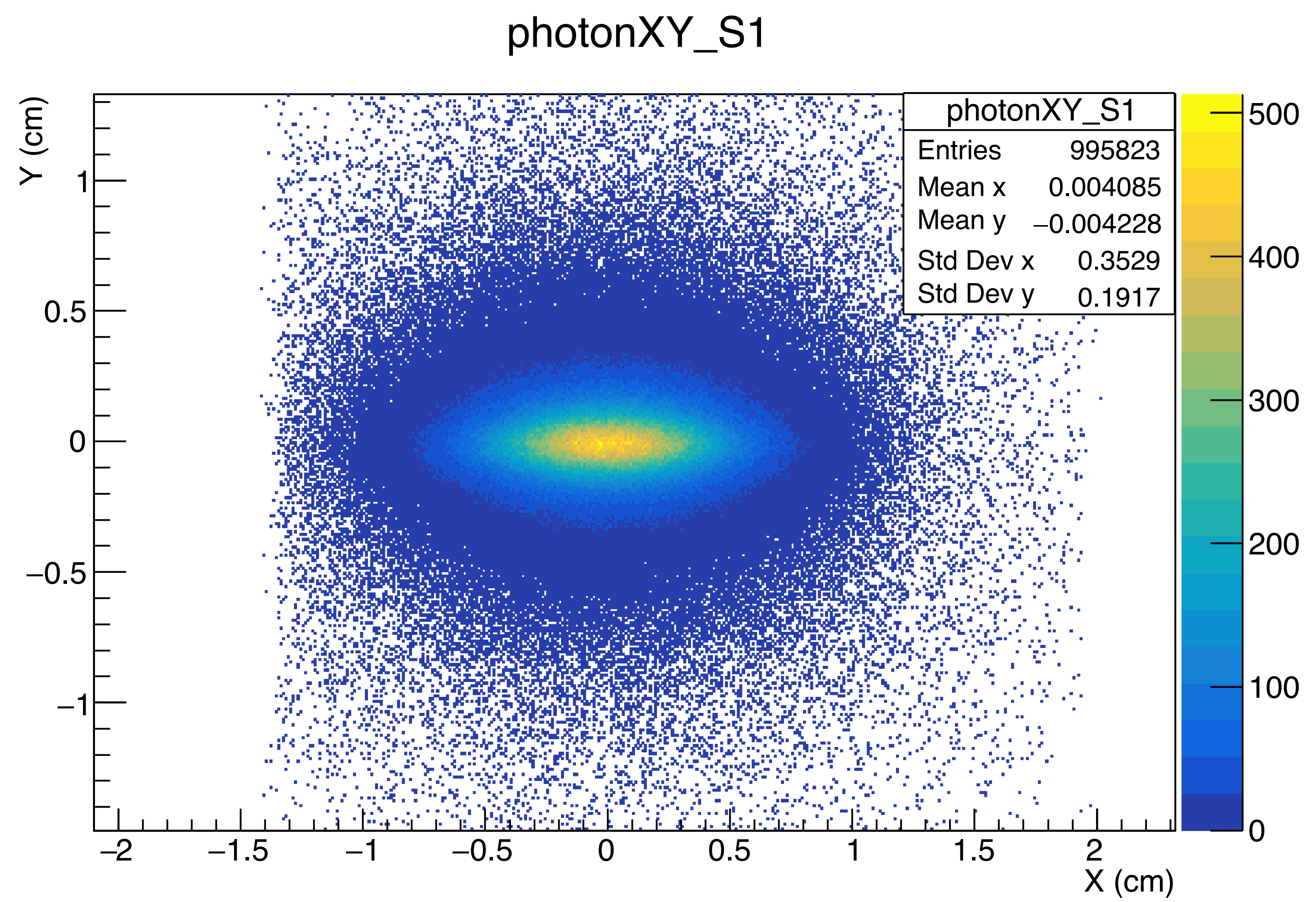
Electron detector positons

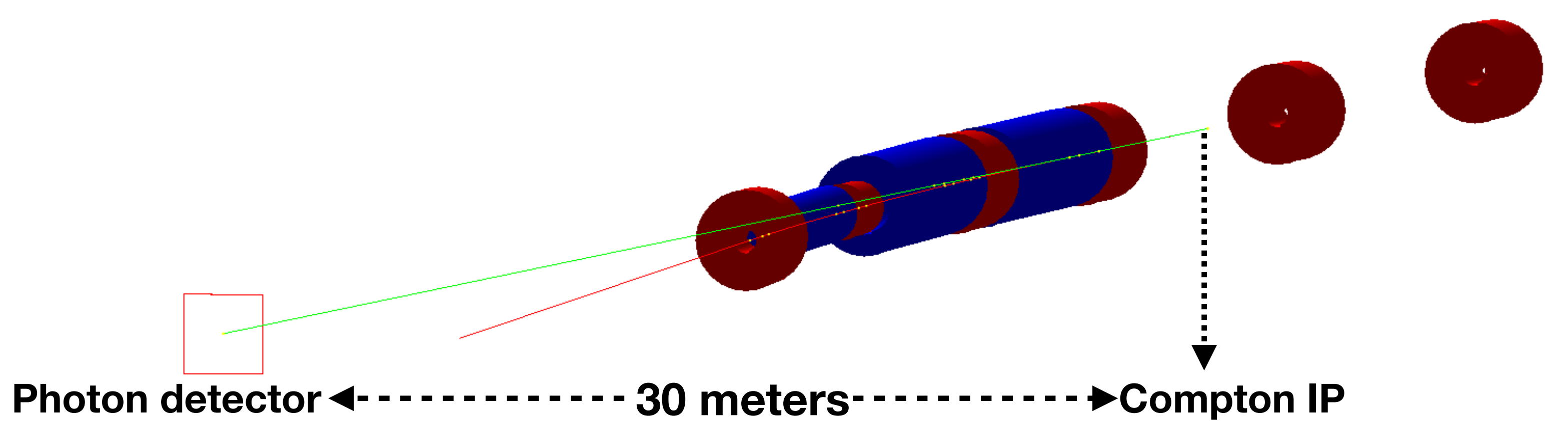
Photon detection

spins aligned

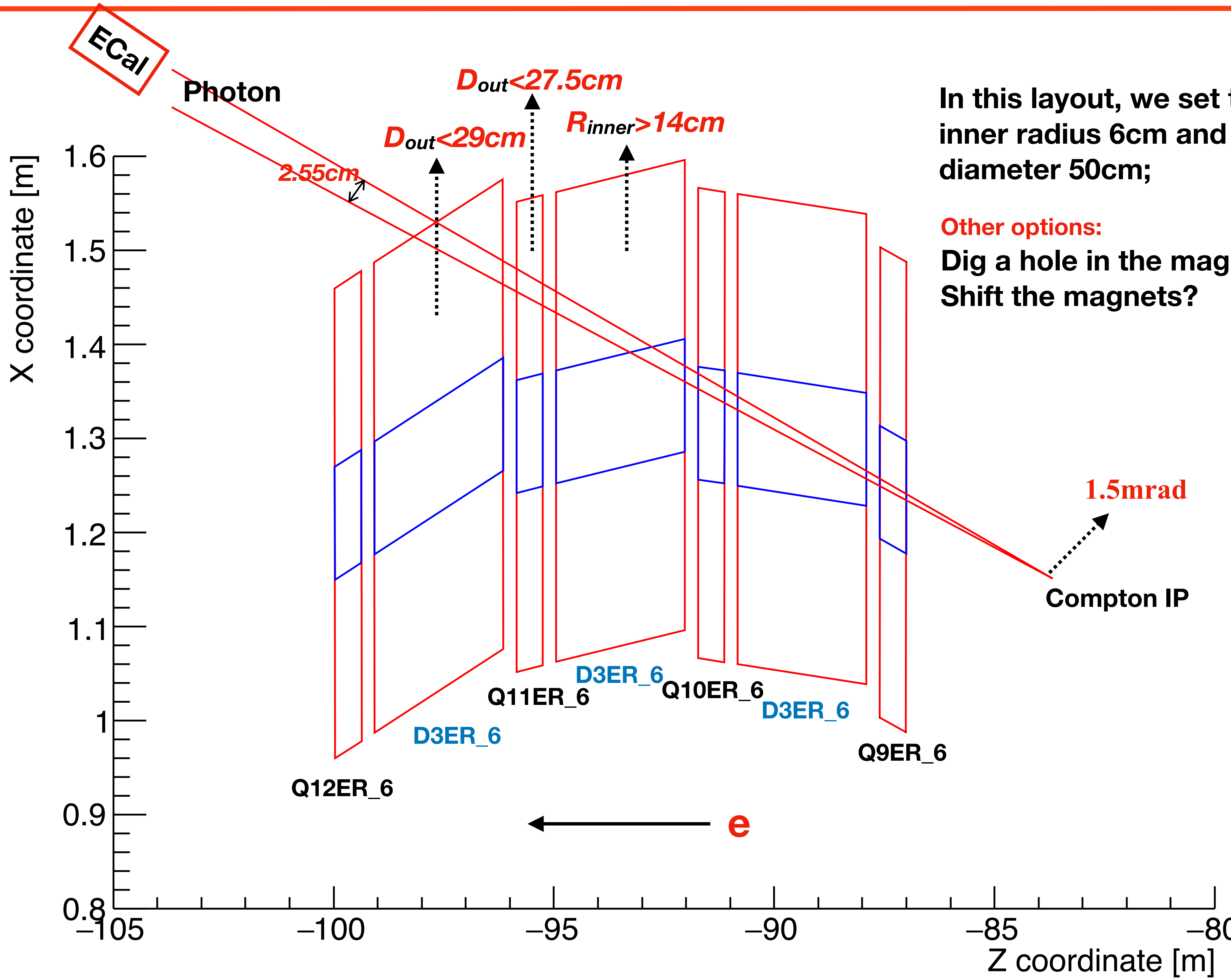


Anti-aligned





Magnets constraints in IP6 Rear



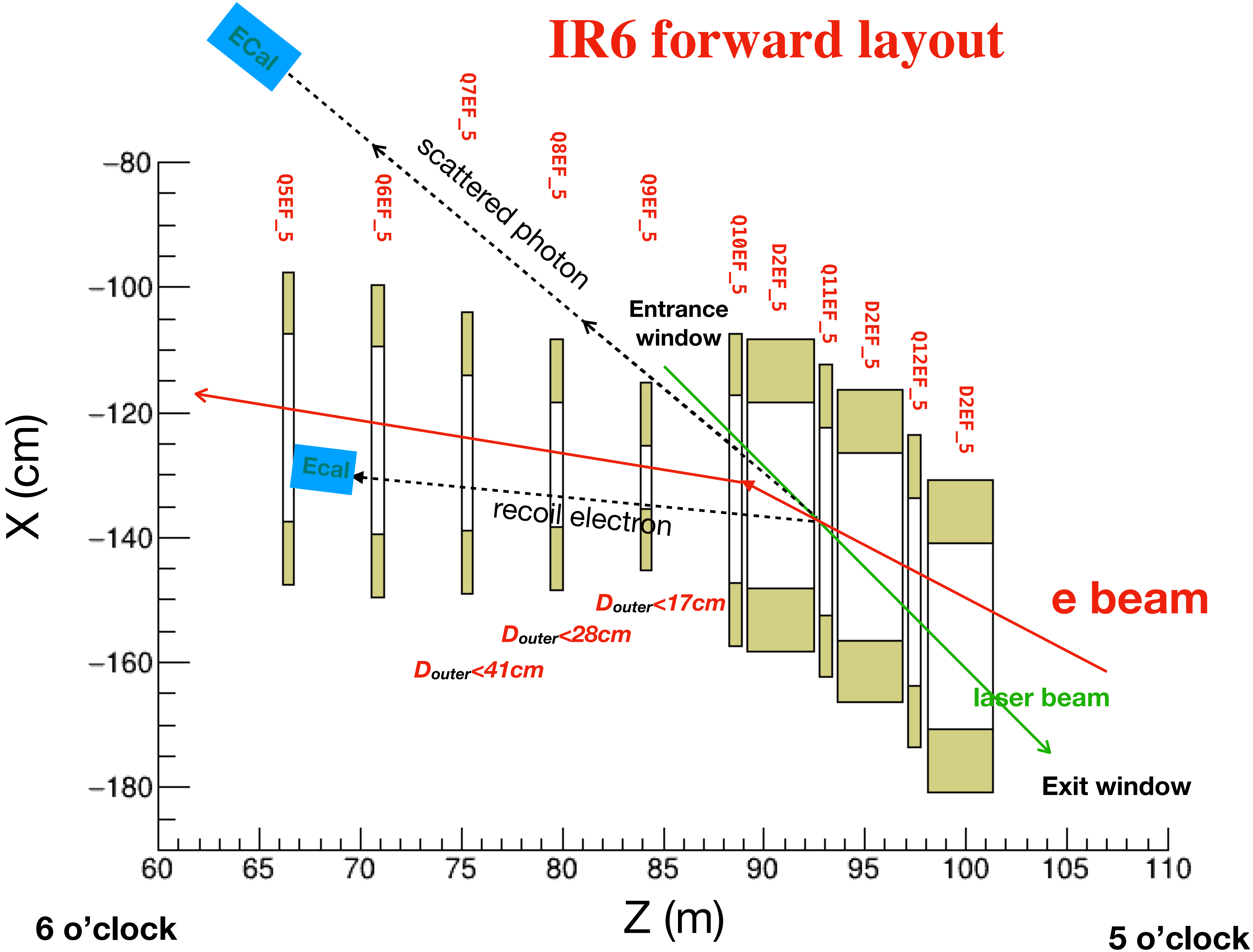
In this layout, we set the default inner radius 6cm and default diameter 50cm;

Other options:

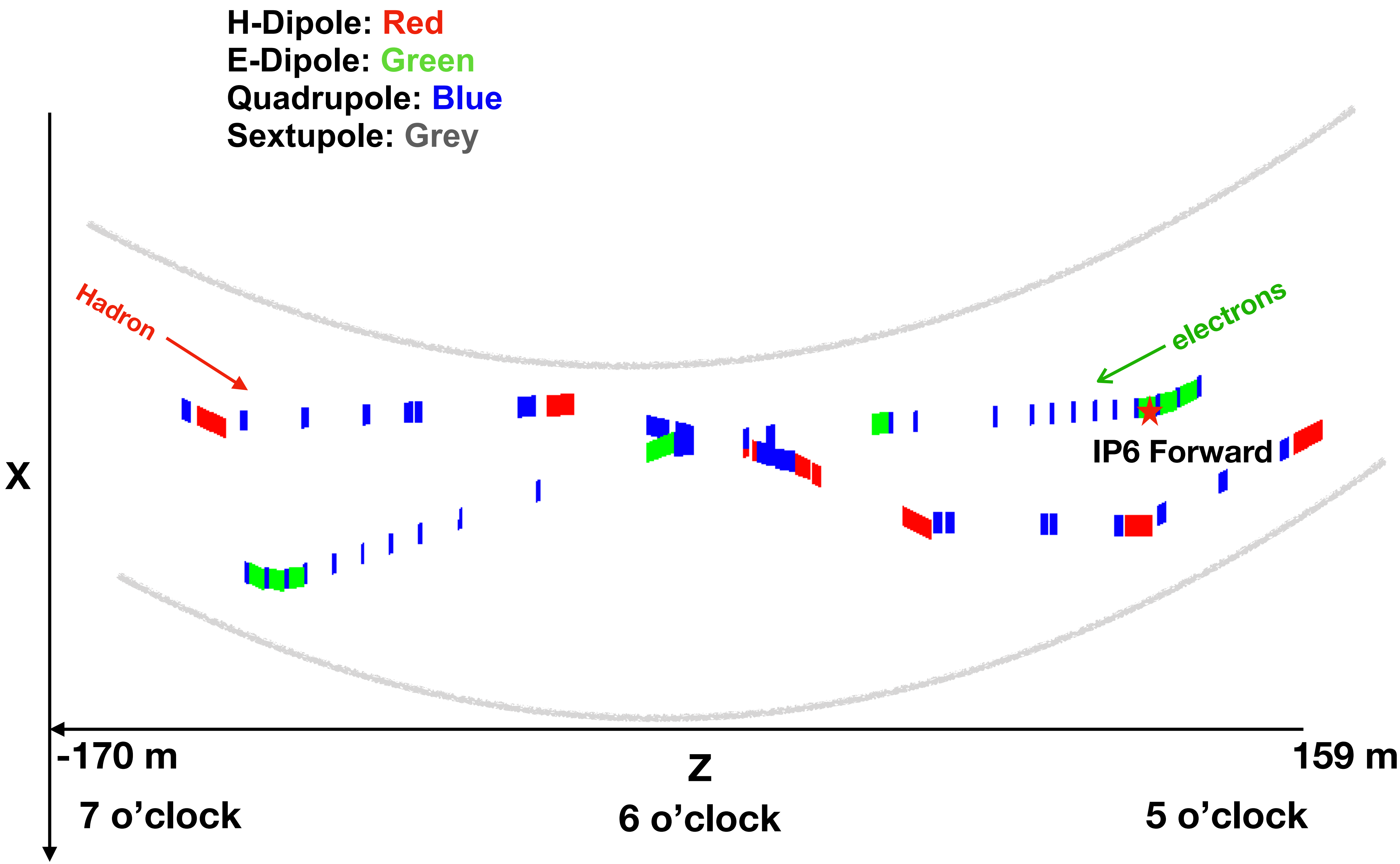
Dig a hole in the magnets?

Shift the magnets?

IR6 forward layout

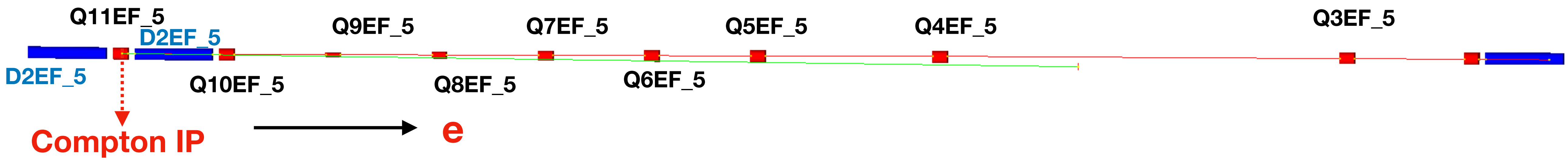


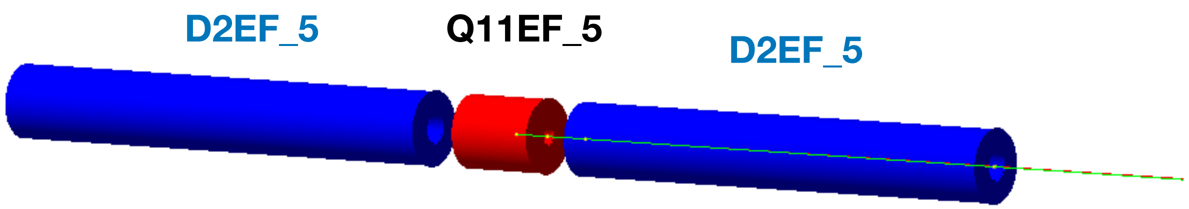
IR6 layout

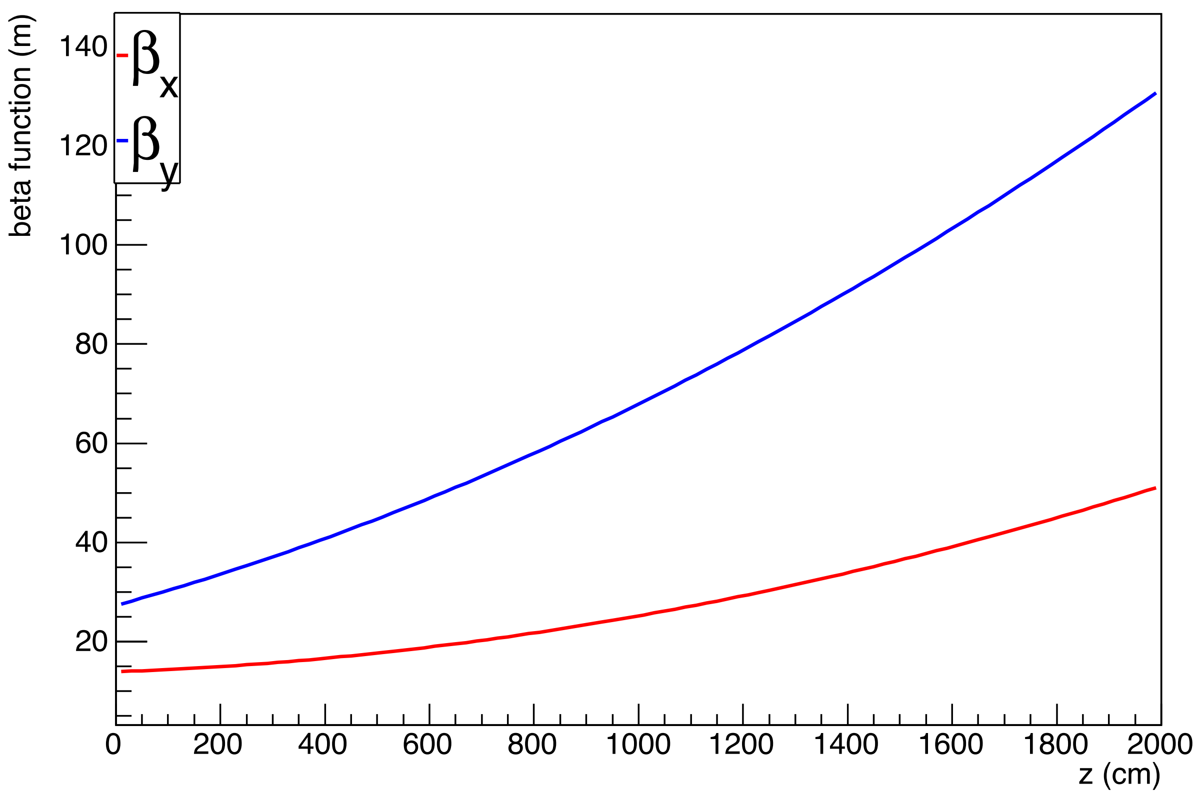

H-Dipole: Red
E-Dipole: Green
Quadrupole: Blue
Sextupole: Grey
Hadron
electrons
IP6 Forward
X
-170 m
Z
159 m
7 o'clock
6 o'clock
5 o'clock

Redesign Electron Forward Beamline

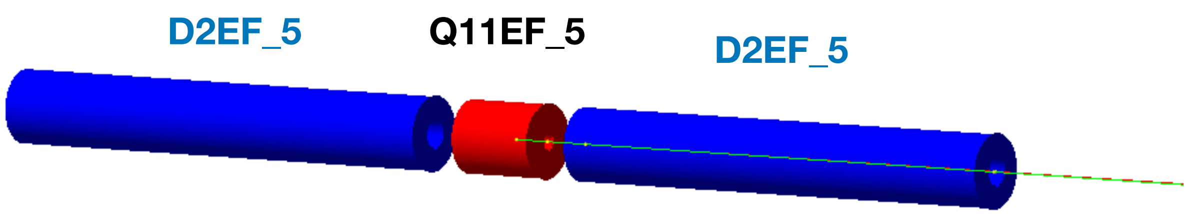
Current beamline

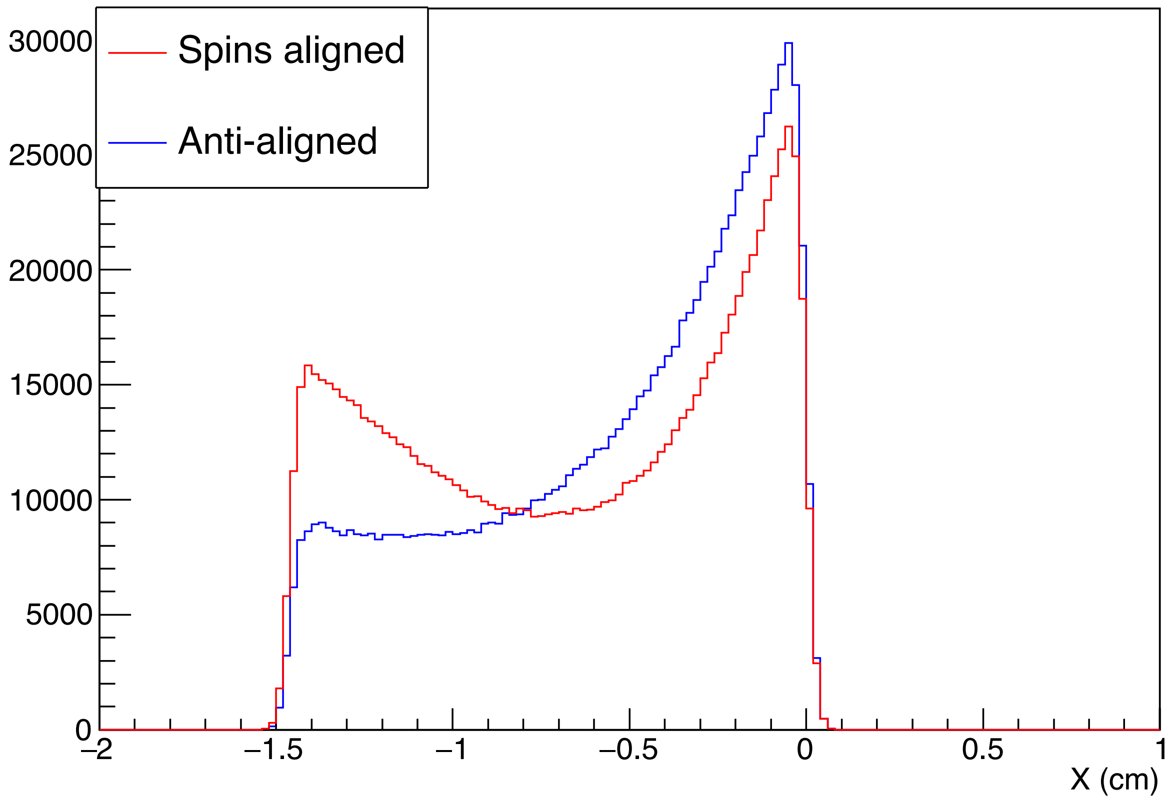


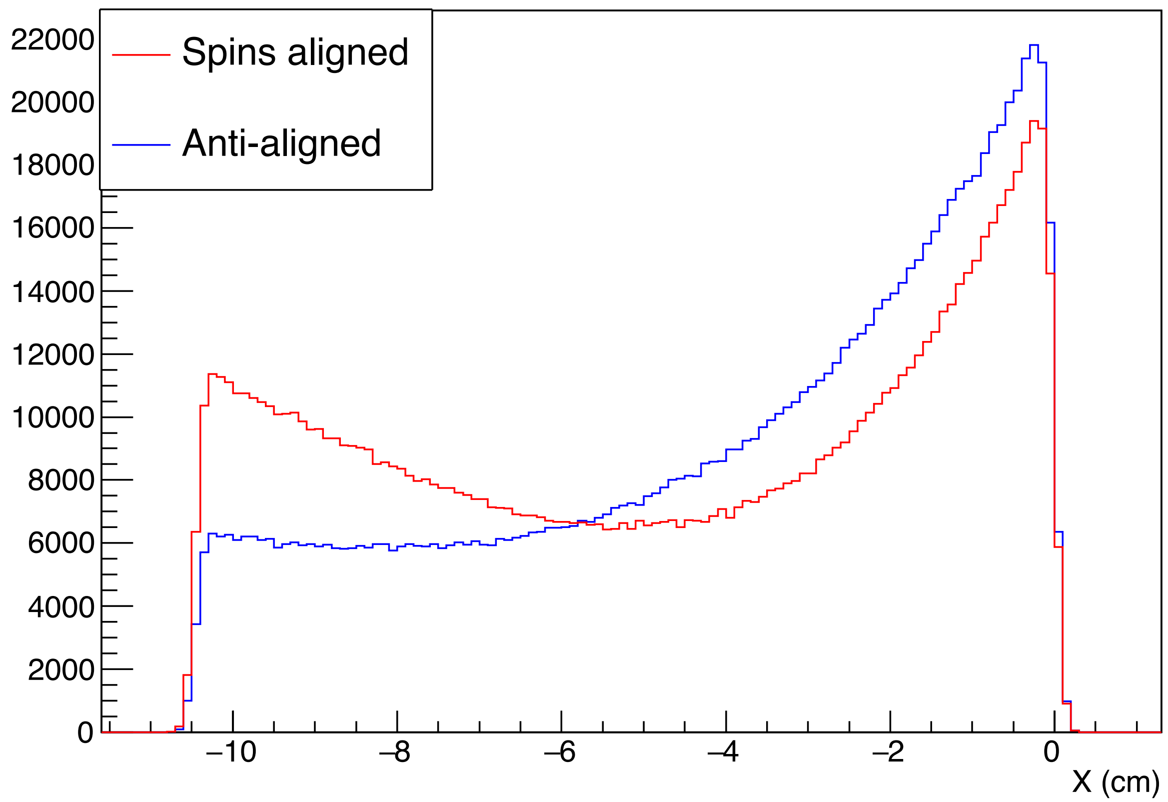




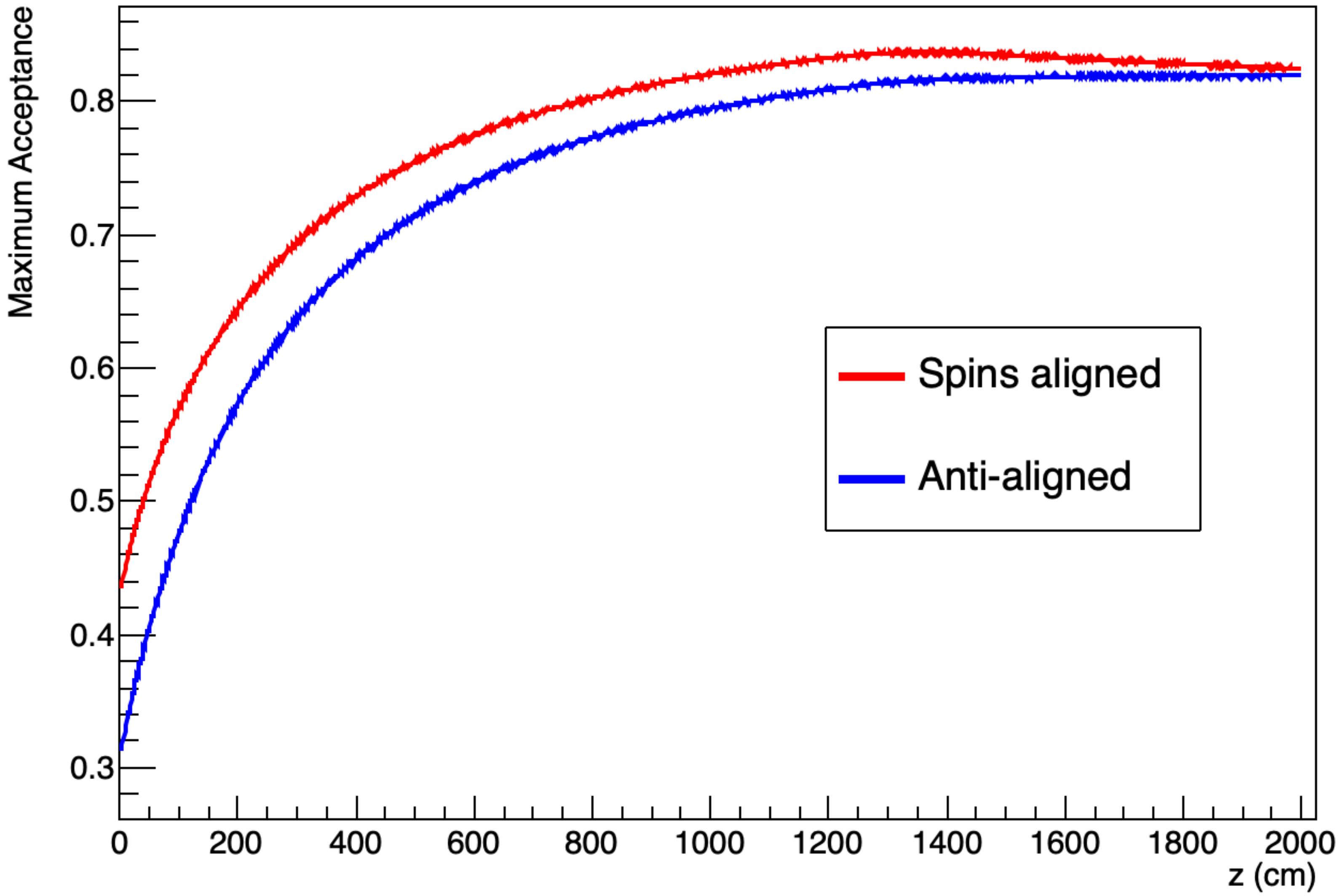
Redesign Electron Forward Beamline

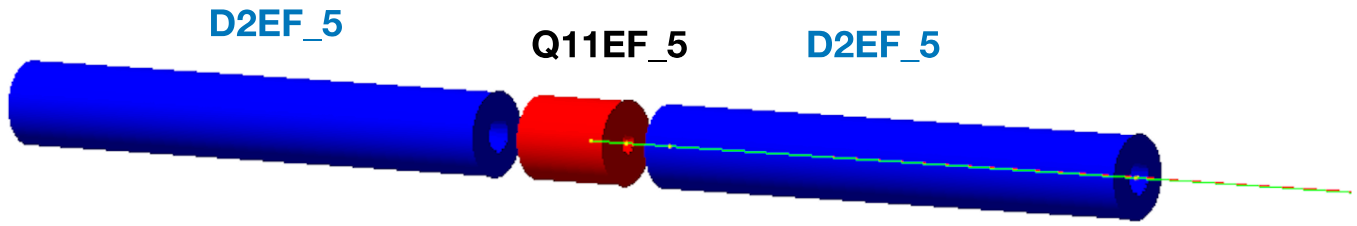






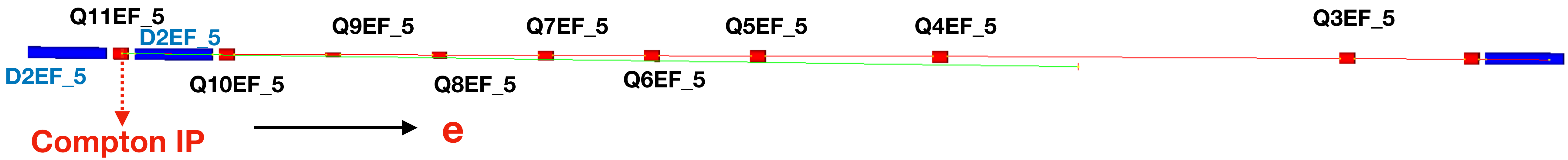
Maximum Acceptance for Recoil Electron

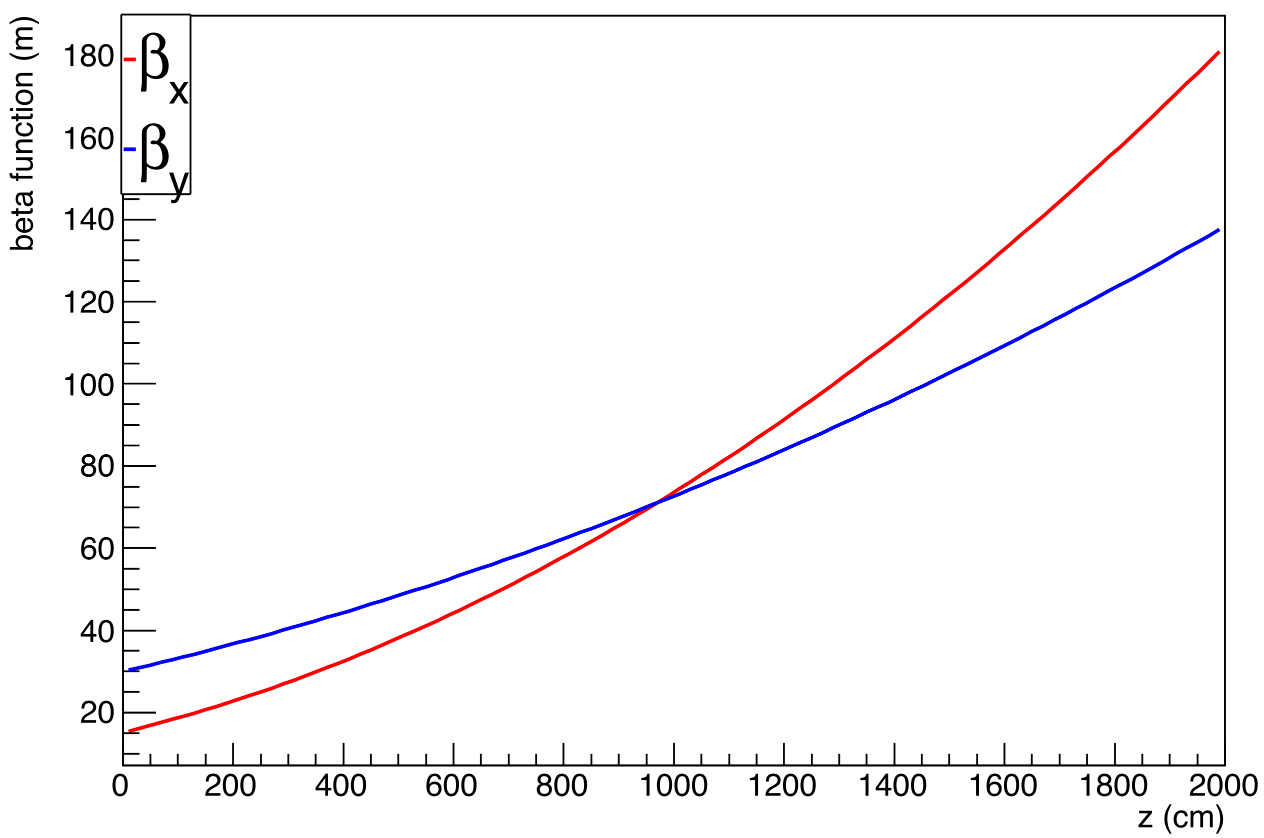




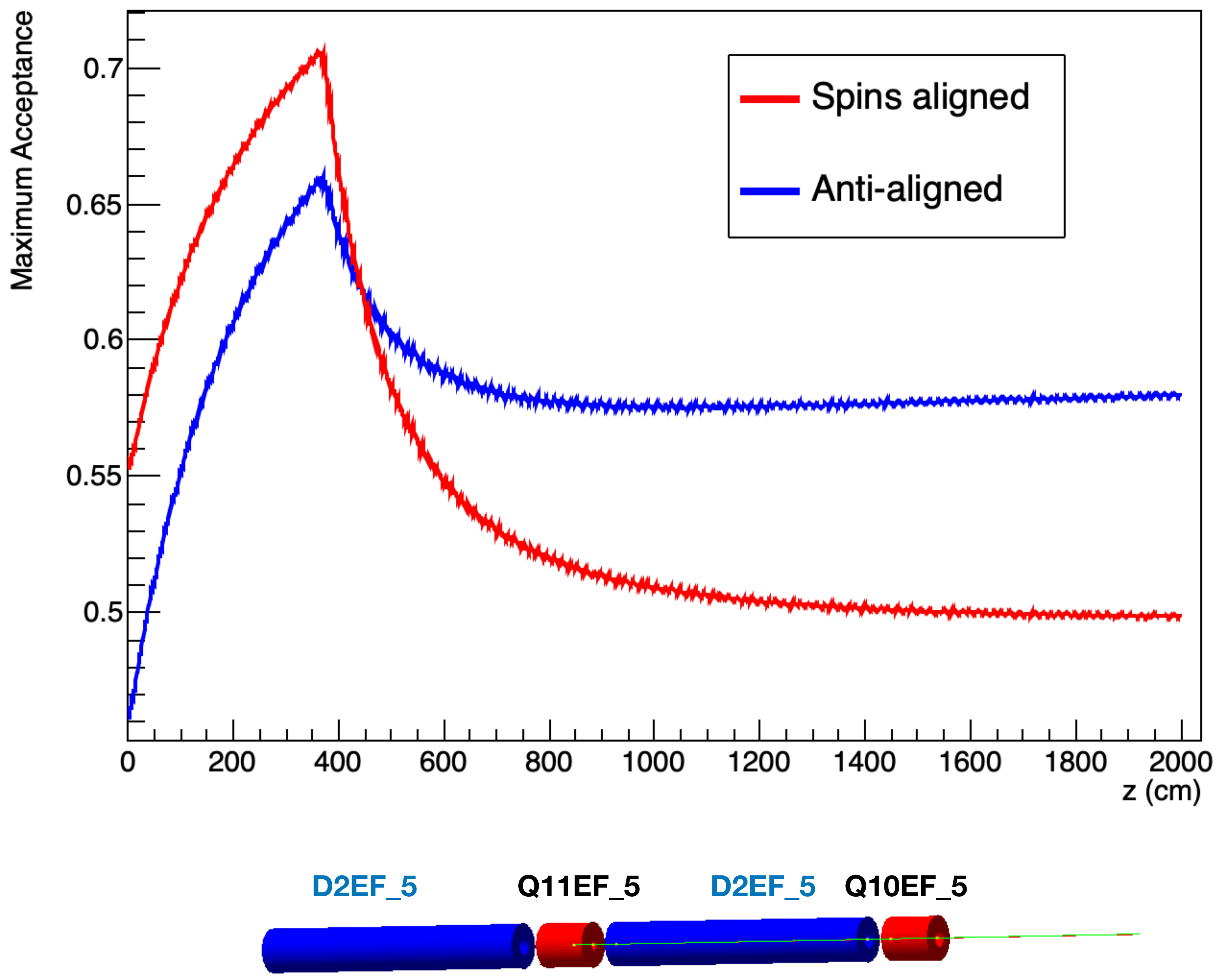
Redesign electron forward beamline

Current beamline

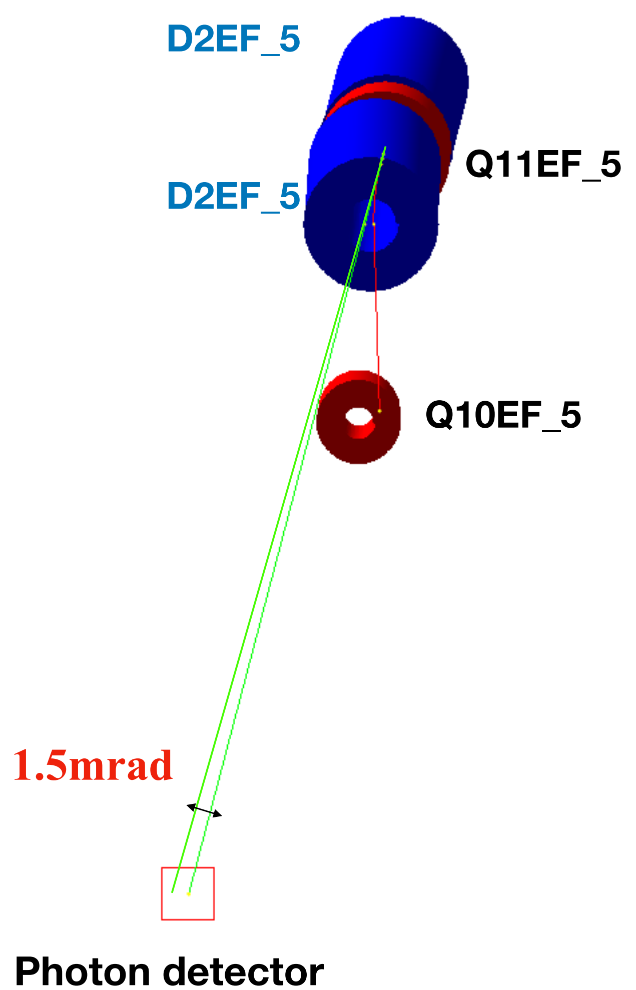


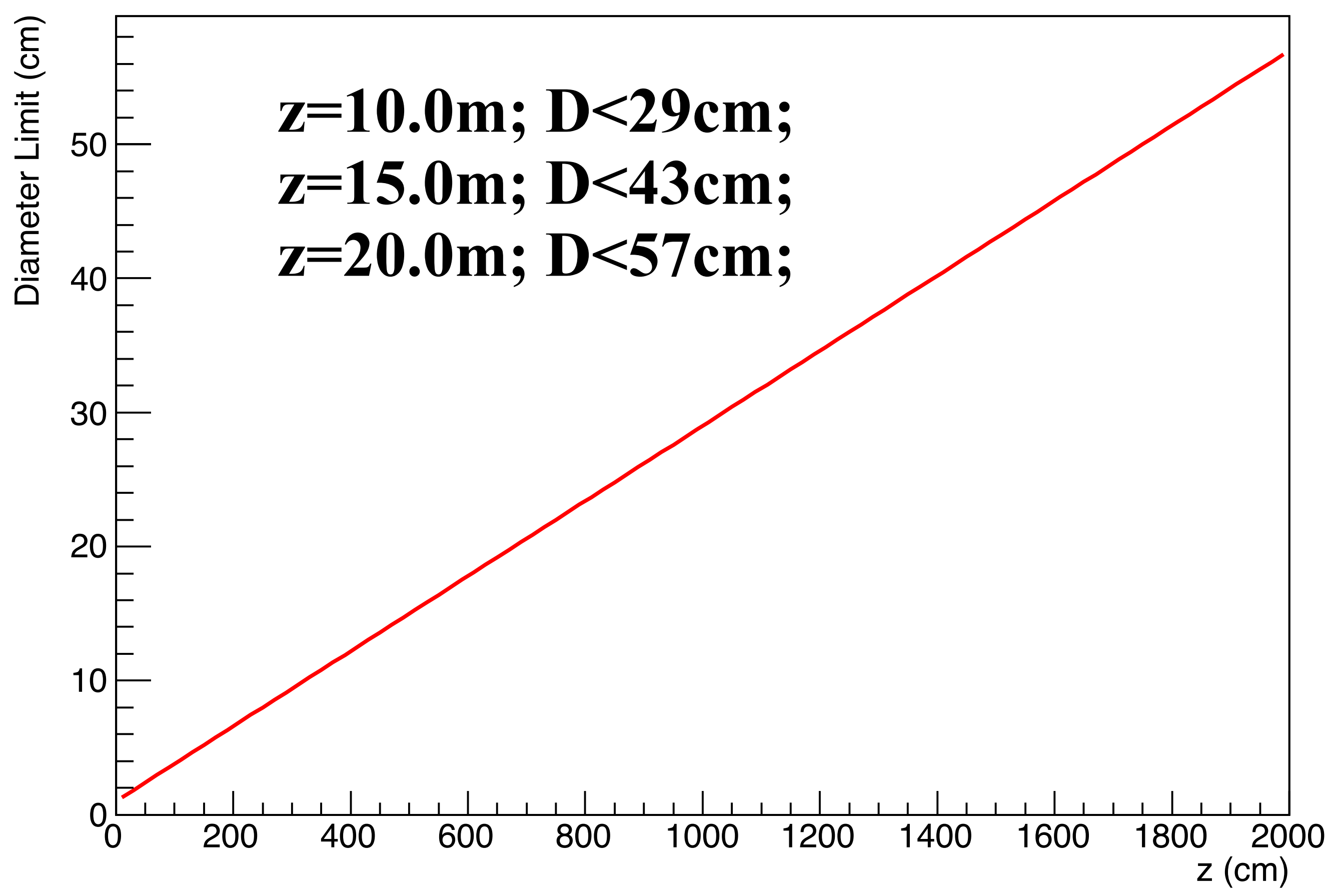


Maximum Acceptance for Recoil Electron



Diameter Limit of the First Element

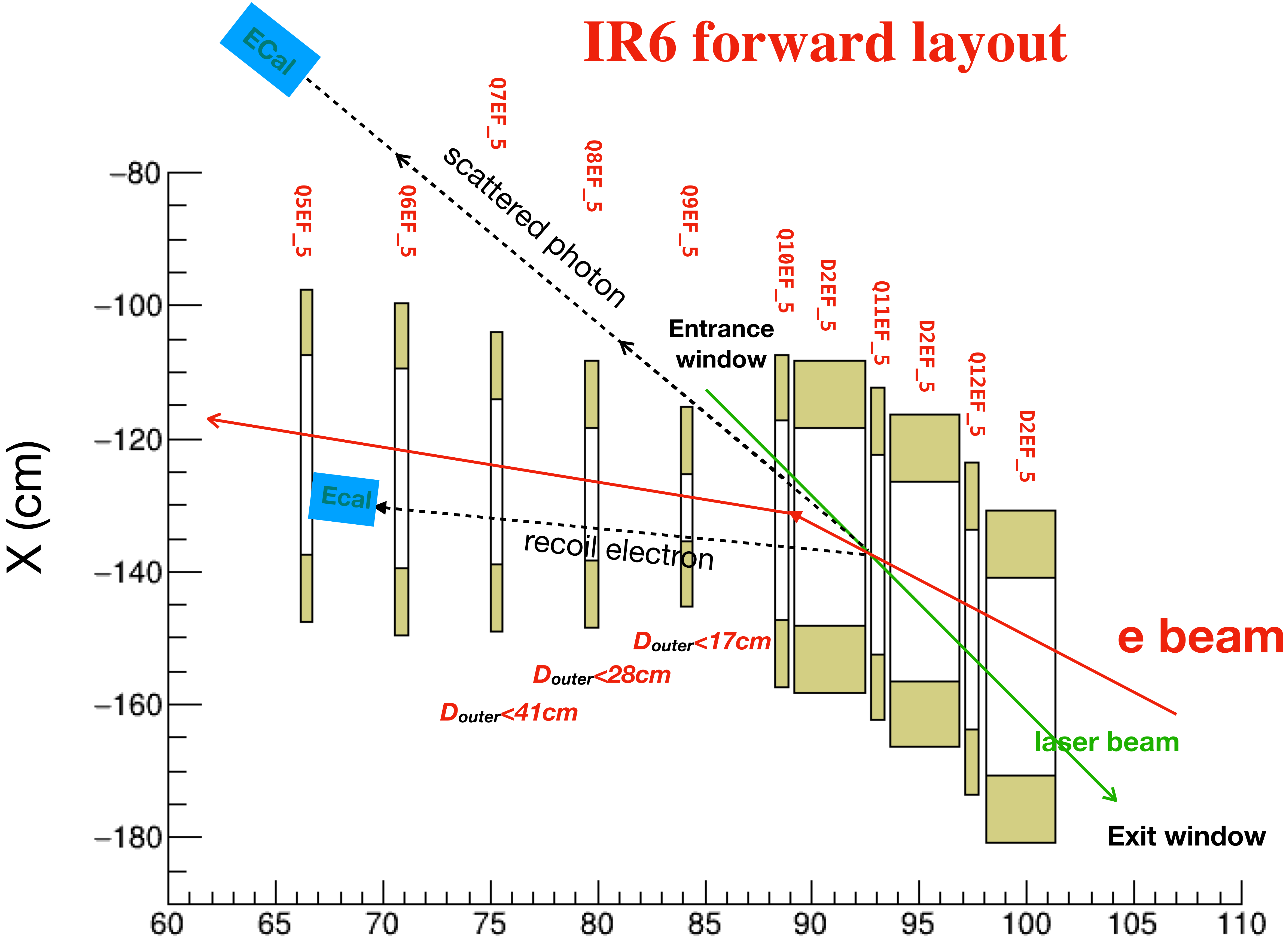




Thanks!

Backup

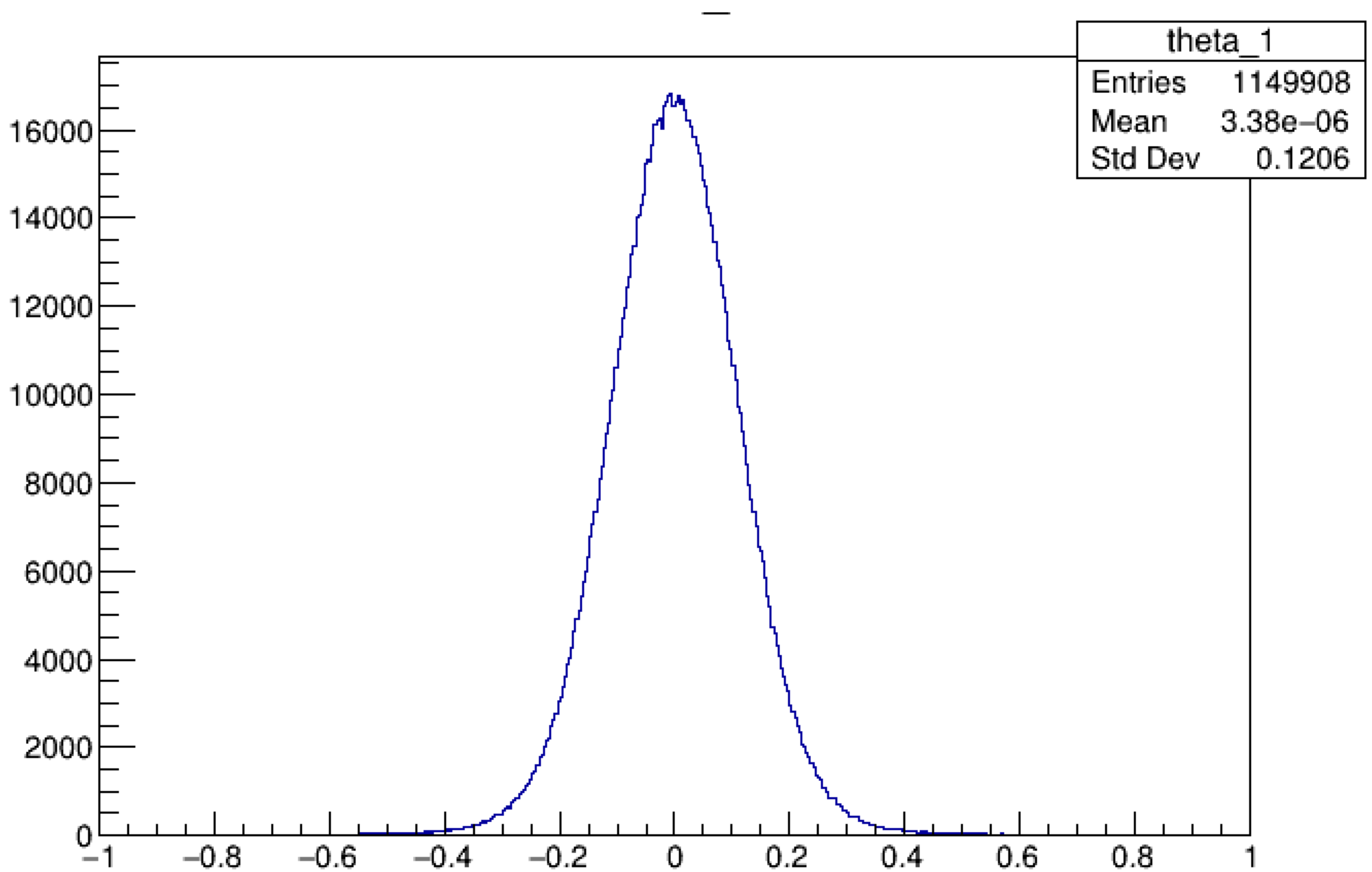
IR6 forward layout



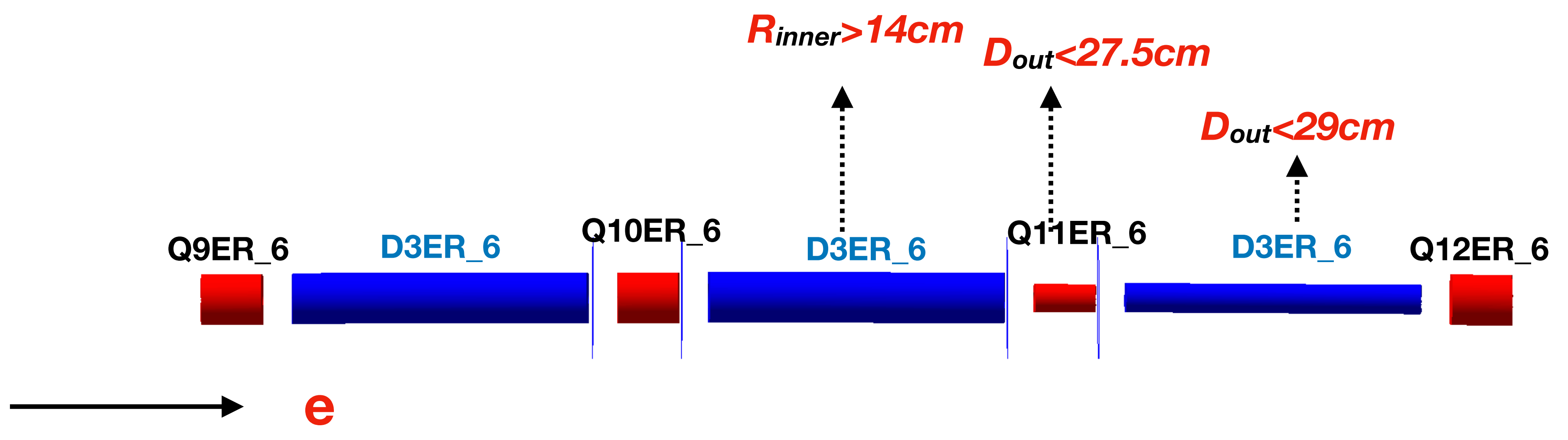
6 o'clock

5 o'clock

Theta distribution of scattered photon



Magnets constrain in IP6 Rear



Other options:

Studying the possibility to dig a hole in the magnets…