LHeC Detector Interaction Region - Discussion (Intro)

- Accelerator - Options
- SR Calculations
- Beam Pipe / Detector Dimensions

Accelerator → Detector Design

- Luminosity and acceptance depend on physics program
  - we prepare for two different interaction region setups still (hope for one setup only)
    $L_{ep} \approx 10^{33}\ cm^{-2}\ s^{-1}$, $10° < \theta < 170°$ - HighQ^2 Setup
    $L_{ep} \approx 10^{32}\ cm^{-2}\ s^{-1}$, $1° < \theta < 179°$ - LowQ^2 Setup
  - Interplay of optics, synchrotron radiation and beam-beam interaction; handling of second proton beam
  - The design dominated by separation scheme e.g. head-on collisions vs. crossing angle of beams, focussing quads - major source for SR currently;
  - beam pipe dimensions; **Dipoles** integrated in inner detector structure (see below)?
  - Linked with the detector layout and design - p_T measurement down to small θ (near 1° and 179°, resp.) - fwd. Toroid
  - → An iteration needed now

LHeC – general parameters

e- beam	RR	LR ERL	LR "p-140"
e- energy at IP[GeV]	60	60	140
luminosity [10^{32} cm^{-2}s^{-1}]	17.1	10.1	0.44
polarization [%]	5 - 40	90	90
bunch population [10^9]	26	2.0	1.6
e- bunch length [μm]	10000	300	300
bunch interval [ns]	25	50	50
transv. emit. $\gamma\varepsilon_{x,y}$ [mm]	0.58, 0.29	0.05	0.1
rms IP beam size $\sigma_{x,y}$ [μm]	30, 16	7	7
e- IP beta funct. $\beta^*_{x,y}$ [m]	0.18, 0.10	0.12	0.14
full crossing angle [mrad]	0.93	0	0
geometric reduction H_{hg}	0.77	0.91	0.94
repetition rate [Hz]	N/A	N/A	10
beam pulse length [ms]	N/A	N/A	5
ER efficiency	N/A	94%	N/A
average current [mA]	131	6.6	0.27
tot. wall plug power[MW]	100	100	100

p- beam	RR	LR
bunch pop. [10^{11}]	1.7	1.7
tr.emit. $\gamma\varepsilon_{x,y}$ [μm]	3.75	3.75
spot size $\sigma_{x,y}$ [μm]	30, 16	7
$\beta^*_{x,y}$ [m]	1.8,0.5	0.1[$]
bunch spacing [ns]	25	25

[$] smaller LR p-β^* value than for nominal LHC (0.55 m):
- reduced l^* (23 → 10 m)
- only one p beam squeezed
- new IR quads as for HL-LHC

B. Holzer,
M. Klein,
F. Zimmermann

IR layout w. head-on collision

LR - Design M.Sullivan - Elliptical Beam Pipe1:

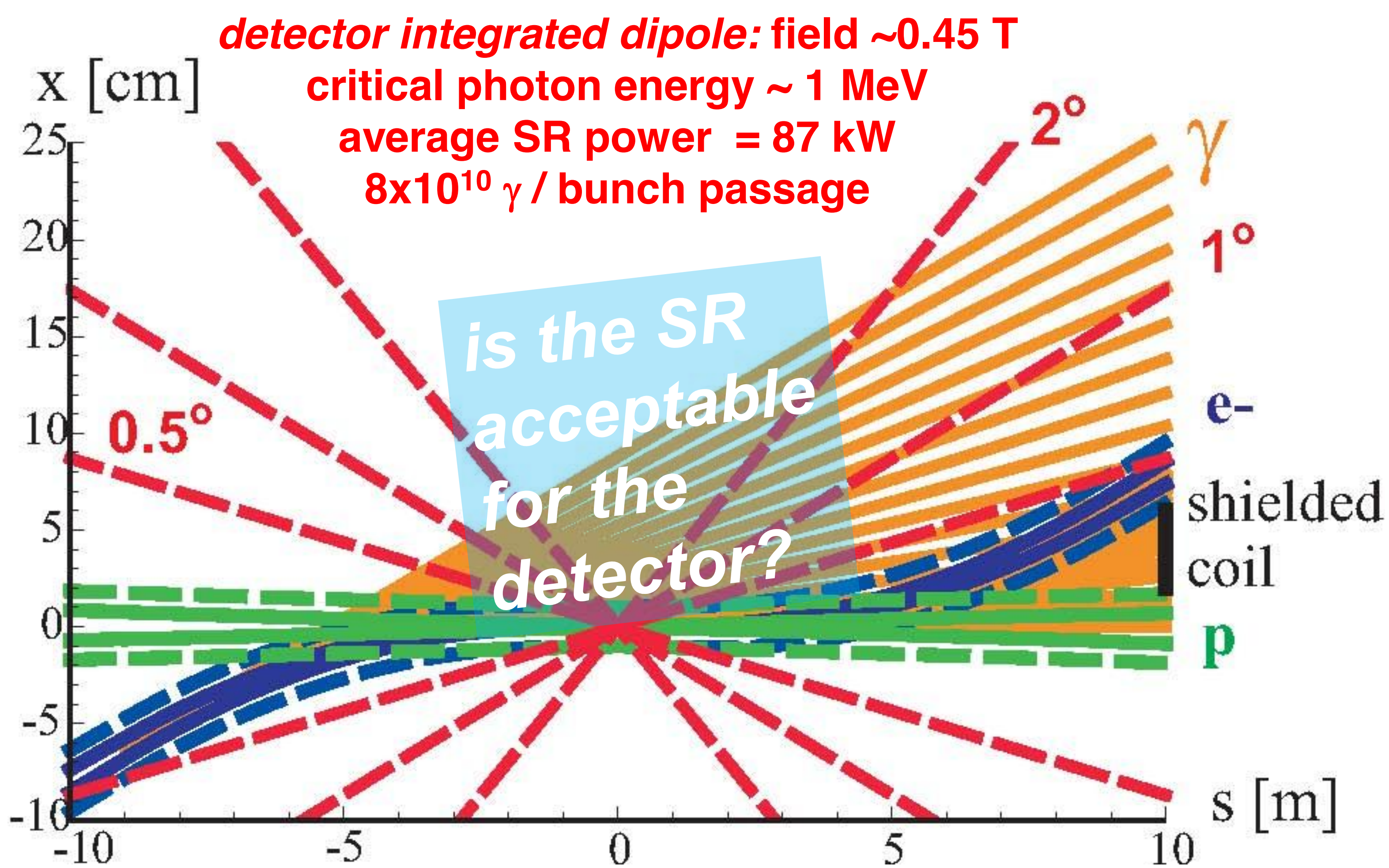
inner-$\varnothing_x$ = 12cm

inner-$\varnothing_y$ = 5cm

outer-$\varnothing_x$ = 12.8cm

outer-$\varnothing_y$ = 5.8cm

➟ thickness: 0.4cm



Beam envelopes of 10σ (electrons) [solid blue] or 11σ (protons) [solid green], the same envelopes with an additional constant margin of 10 mm [dashed], the synchrotron radiation fan [orange], and the approximate location of the magnet coil between incoming protons and outgoing electron beam [black].

INTERACTION-REGION DESIGN OPTIONS FOR A LINAC-RING LHEC by F.Zimmermann et.al. submitted IPAC'10

Answer: SR problematic - to be checked

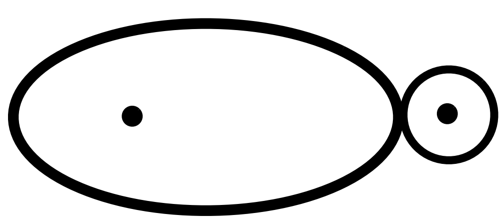
how about 2nd LHC proton beam?

2nd beam must be transported across LHeC IR

<u>two possibilities:</u>

(1) common IR vacuum chamber; **second beam unsqueezed**

(2) detector with a bypass hole (c.f. Tevatron D0)

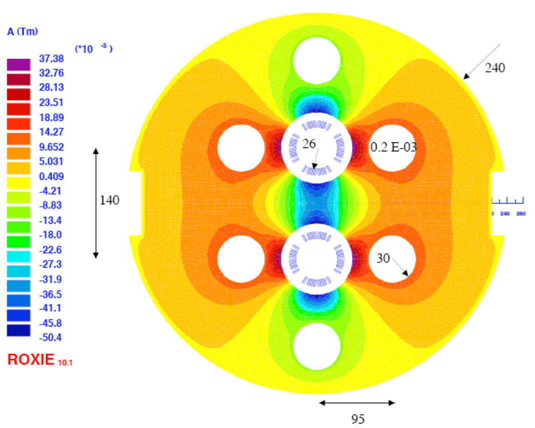


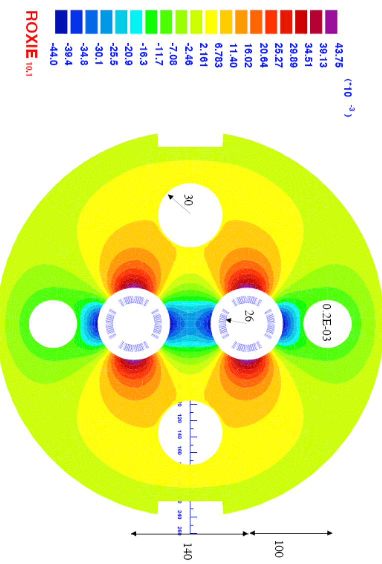
CLIC-LHeC Synergies & KEK Trip Report, Frank Zimmermann, CLIC Meeting 20 August 2010

Which version we have to live with?

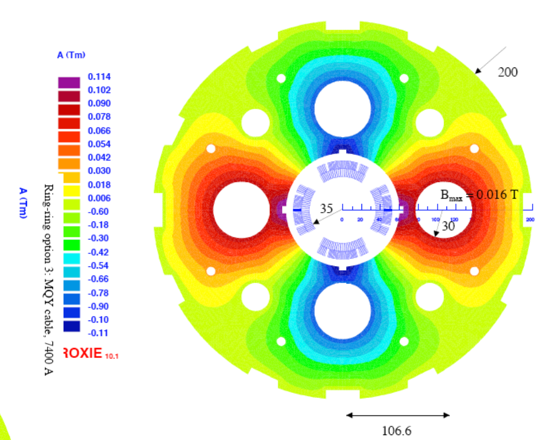
5 Remaining Options for Ring-Ring

Ring-Ring option2, double aperture, MQY cable, 7400 A

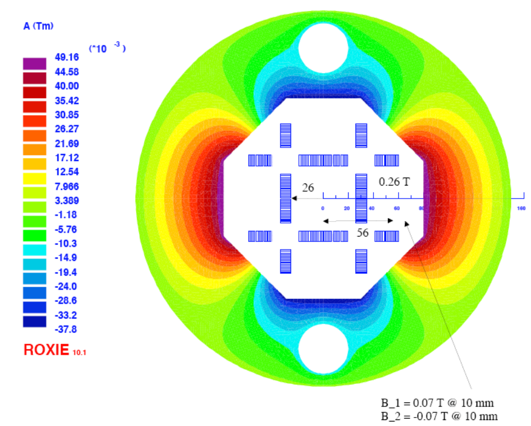




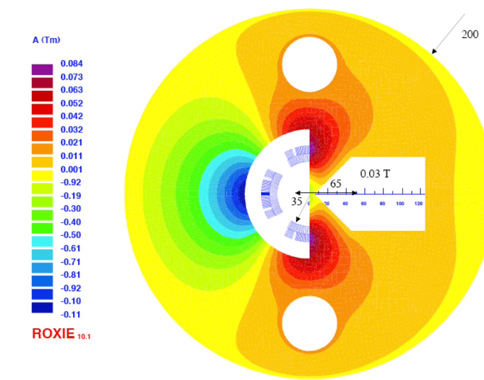
Ring-Ring option. Single aperture magnet for two proton beams, 127 T/m, 4600 A, MQY cable



Ring-ring option with racetrack coils, MQY non-keystoned cable, 5400 A



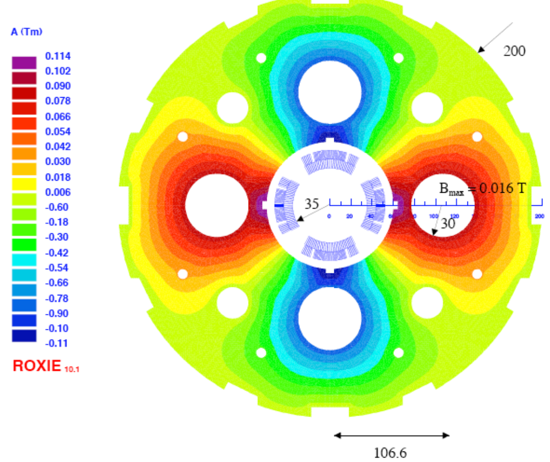
Ring-ring option half-quadrupole, 4900 A, Gradient 137 T/m, + 2.5 T dipole field from feeddown



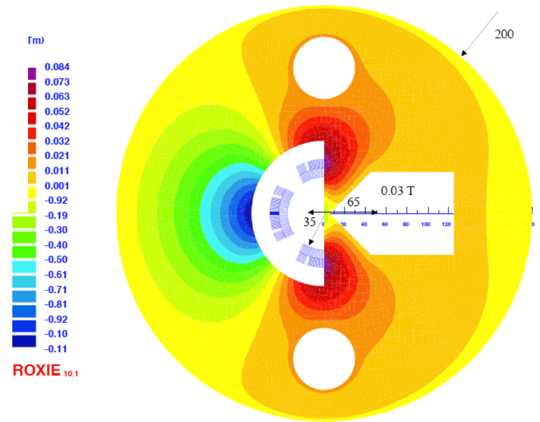
Double aperture (vertical)	Double aperture (horizontal)	Single aperture (for two beams)	Block coil	Mirror
7400 A MQY cable	7400 A MQY cable	4600 A MQY cables	4600 A MQY (non-keyst.)	4900 A MQY cables
95 mm	100 mm	107 mm	56 mm	65 mm
0.2 E -3 T	0.2 E -3 T	0.016 T	0.07 T + quad comp.	0.03 T

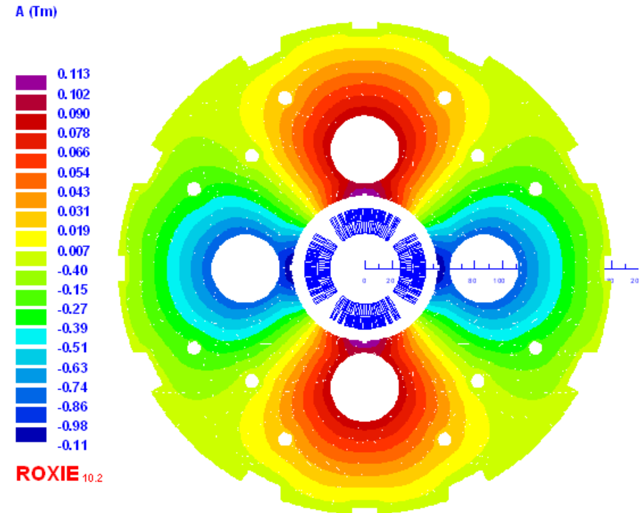
Comparison Q1 for Ring-Ring and Linac-Ring

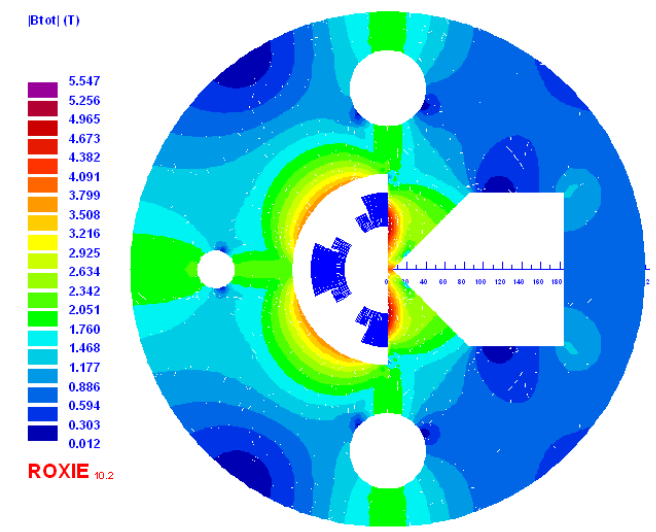
Ring-Ring option. Single aperture magnet for two proton beams, 127 T/m, 4600 A, MQY cable



g-ring option half-quadrupole, 4900 A, Gradient 137 T/m,
.5 T dipole field from feeddown



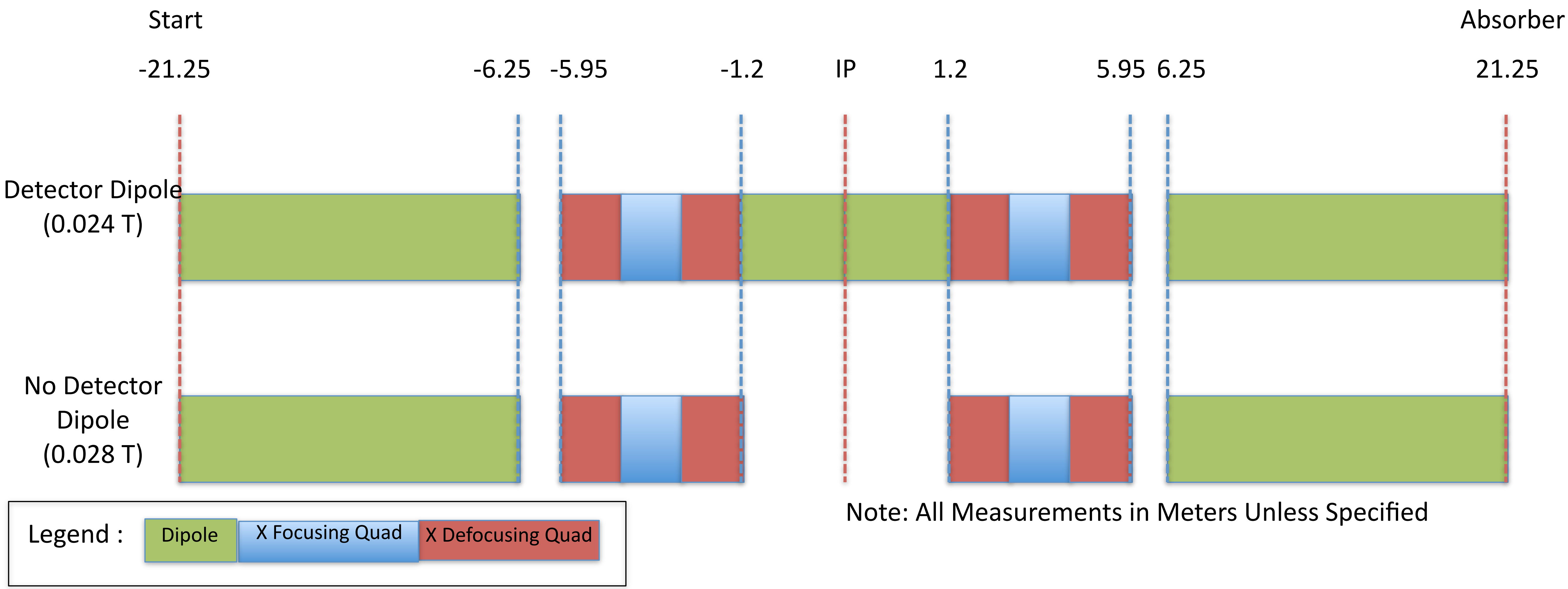




4600 A MQY cable	4900 A MQY	NbTi: 6700 A, 248 T/m at 88% LL Nb3Sn (HFM46): 8600 A, 311 T/m, at 83% LL	NbTi: 4500 A, 145 T/m, 3.6 T at 87% Nb3Sn (HFM46): 5700 A, 175 T/m, 4.7 T at 82% on LL (4 layers)
35 mm aperture 107 mm beam sep.	35 mm (half) app. 65 mm beam sep.	23 mm app. 87 mm beam sep.	46 mm (half) app. 63 mm beam sep.
0.016 T fringe field in electr. pipe	0.03 T	0.03 T, 3.5 T/m 0.09 T, 9 T/m	0.37 T, 18 T/m 0.5 T, 25 T/m

NbTi at 1.8 K, Nb3Sn at 4.2 K

Two Options - RR



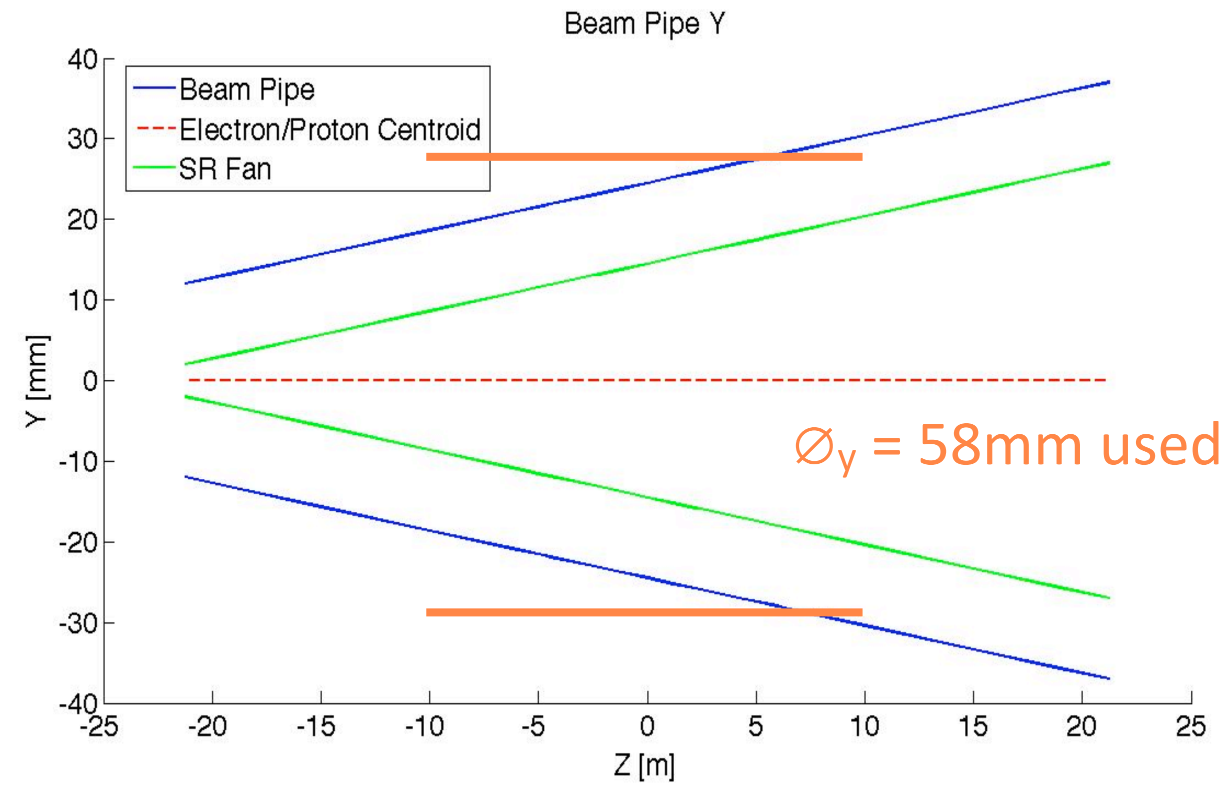
- In the above diagram two options are presented.
  Both options obtain a separation of ~50 mm of the interacting proton beam and electron beam at the absorber surface.

- The first option includes two 1.2 meter dipoles located inside the detector with opposite polarity.
  This option requires a uniform dipole field of 0.024 T to obtain the desired separation.
  In this case the simulation was done with a generic uniform field and so the radial placement of the detector dipoles is not fixed.

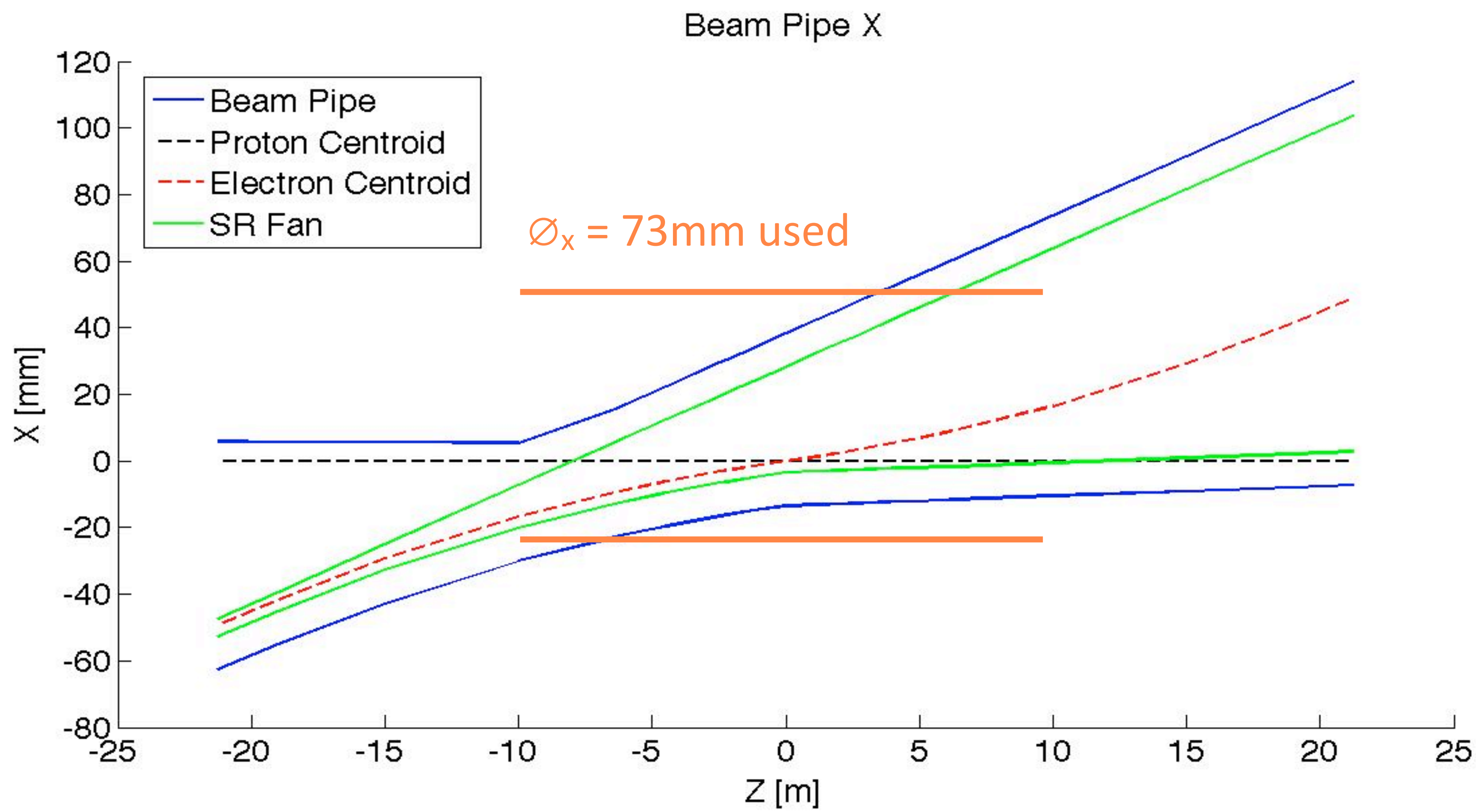
- The second option does not include any dipoles inside the detector however the field in the remaining elements must be raised to 0.028 T to obtain the same separation.

- In both cases the quadrupole triplets obtain an effective dipole field through offsets.

Beam Pipe Contents*



- The proton centroid was provided by Luke Thompson.
- The electron centroid was found by simulations in GEANT4 using modified MAD-X optics to achieve ~50 mm of separation at the absorber.
- The SR fan is the output of GEANT4 simulations
- The beam pipe is designed from preliminary tolerances however the required tolerance for the SR fan needs to be made clear !



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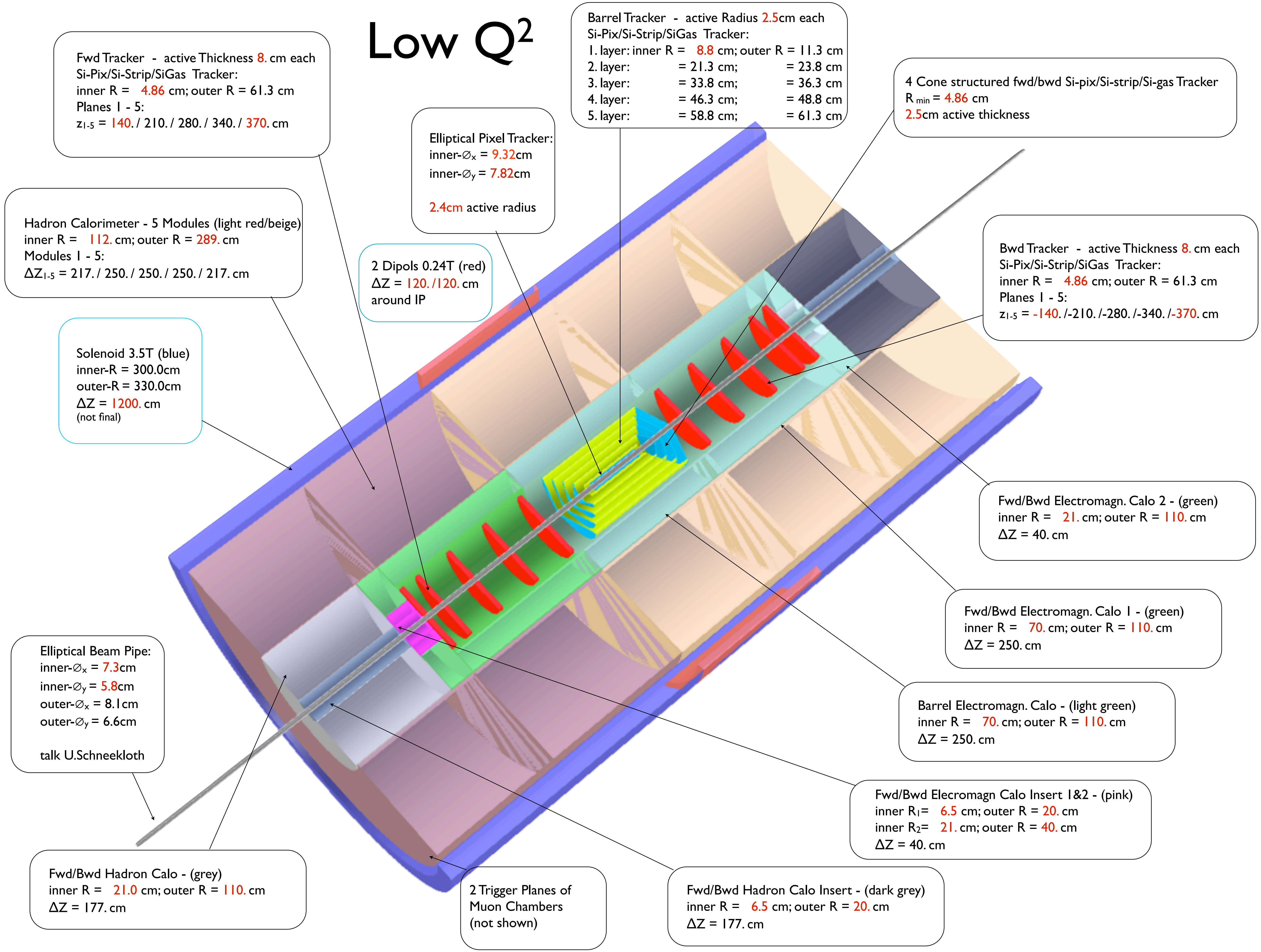
Tolerances needed

*Simulations performed with GEANT4

Synchrotron Radiation Results - Using GEANT4, Nathan Bernard, LHeC Design Meeting, 31-8-10
*based on the optics of L.Thompson

Low Q^2



Fwd Tracker - active Thickness 8. cm each
Si-Pix/Si-Strip/SiGas Tracker:
inner R = 4.86 cm; outer R = 61.3 cm
Planes 1 - 5:
z1-5 = 140. / 210. / 280. / 340. / 370. cm
Elliptical Pixel Tracker:
inner-∅x = 9.32cm
inner-∅y = 7.82cm
2.4cm active radius
Barrel Tracker - active Radius 2.5cm each
Si-Pix/Si-Strip/SiGas Tracker:
1. layer: inner R = 8.8 cm; outer R = 11.3 cm
2. layer: = 21.3 cm; = 23.8 cm
3. layer: = 33.8 cm; = 36.3 cm
4. layer: = 46.3 cm; = 48.8 cm
5. layer: = 58.8 cm; = 61.3 cm
4 Cone structured fwd/bwd Si-pix/Si-strip/Si-gas Tracker
R min = 4.86 cm
2.5cm active thickness
Hadron Calorimeter - 5 Modules (light red/beige)
inner R = 112. cm; outer R = 289. cm
Modules 1 - 5:
ΔZ1-5 = 217. / 250. / 250. / 250. / 217. cm
2 Dipols 0.24T (red)
ΔZ = 120. /120. cm
around IP
Bwd Tracker - active Thickness 8. cm each
Si-Pix/Si-Strip/SiGas Tracker:
inner R = 4.86 cm; outer R = 61.3 cm
Planes 1 - 5:
z1-5 = -140. /-210. /-280. /-340. /-370. cm
Solenoid 3.5T (blue)
inner-R = 300.0cm
outer-R = 330.0cm
ΔZ = 1200. cm
(not final)
Fwd/Bwd Electromagn. Calo 2 - (green)
inner R = 21. cm; outer R = 110. cm
ΔZ = 40. cm
Fwd/Bwd Electromagn. Calo 1 - (green)
inner R = 70. cm; outer R = 110. cm
ΔZ = 250. cm
Elliptical Beam Pipe:
inner-∅x = 7.3cm
inner-∅y = 5.8cm
outer-∅x = 8.1cm
outer-∅y = 6.6cm
talk U.Schneekloth
Barrel Electromagn. Calo - (light green)
inner R = 70. cm; outer R = 110. cm
ΔZ = 250. cm
Fwd/Bwd Elecromagn Calo Insert 1&2 - (pink)
inner R1= 6.5 cm; outer R = 20. cm
inner R2= 21. cm; outer R = 40. cm
ΔZ = 40. cm
Fwd/Bwd Hadron Calo - (grey)
inner R = 21.0 cm; outer R = 110. cm
ΔZ = 177. cm
2 Trigger Planes of
Muon Chambers
(not shown)
Fwd/Bwd Hadron Calo Insert - (dark grey)
inner R = 6.5 cm; outer R = 20. cm
ΔZ = 177. cm

High Q^2

Elliptical Beam Pipe:

inner-$\varnothing_x$ = 7.3cm outer-$\varnothing_x$ = 8.1cm

inner-$\varnothing_y$ = 5.8cm outer-$\varnothing_y$ = 6.6cm

0.8cm wall thickness allows a sandwich structure of the beam pipe
e.g. Be-Nomex-Be or Al-Nomex-Al or any combination of both.
(Nomex= honeycomb of Rohacell_Airex X0=1380cm
compared to Be X0= 35cm)

From: Raymond Veness
Subject: **RE: Beam Pipe - short info**
Date: 4, October, 2010 12:09:08 PM GMT+02:00
To: peter kostka
Cc: Alessandro Polini , jonathan.bosch@cern.ch

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Hi Peter,

We have some preliminary results for the beampipe.

Can we meet to go through this together?

Perhaps some time on Wednesday?

Best regards,

Ray
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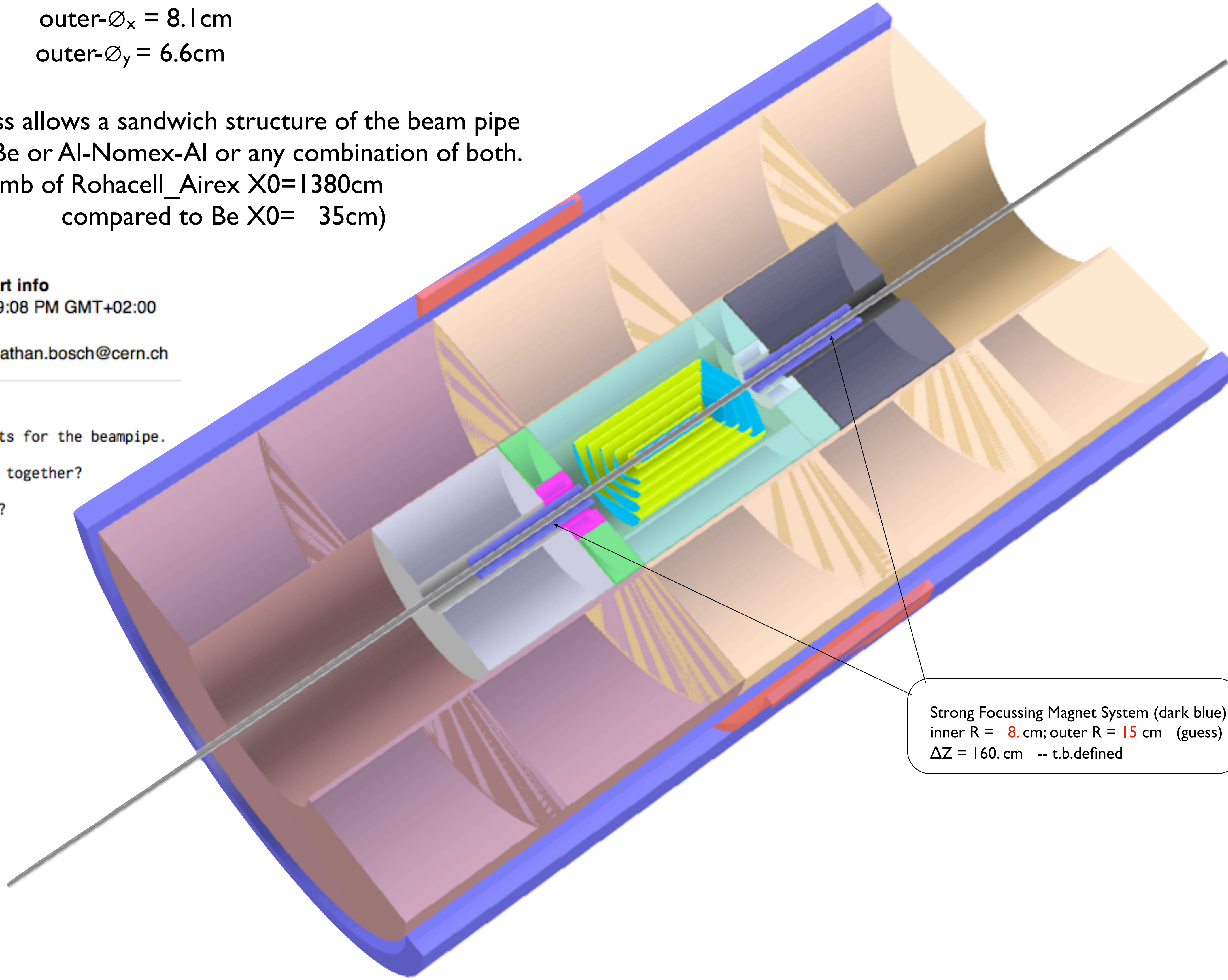

Questions to be answered

- Synchrotron Radiation - geometry, intensity, backscattering - Optic ?
- Second proton beam?
- Dipoles inside the detector needed?

SR Characteristics using GEANT4 Simulations

Characteristic	Detector Dipole	No Detector Dipole
E [GeV]	60	60
I [mA]	100	100
Detector Dipole Length [m]	2.4	0
B [T]	0.024	0.028
$\theta_{Initial}$* [mrad]	3.6	3.8
$\theta_{Crossing}$* [mrad]	1.108	1.104
E_c [keV]	102.79	108.05
E_μ [keV]	31.65	33.27
E_σ [keV]	57.47	60.41
λ [m]	2.585	2.579
γ/e-	7.7025	8.2043
P [kW]	24.3756	27.2986
Separation** [mm]	49.067	49.795

*θ is the angle between the electron and proton momentum vectors

** The separation is the displacement between the proton and electron centroids at the absorber