Compensation of the detector solenoid field

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1st FCC-ee mini-workshop on detector requirements,

17/6/2015

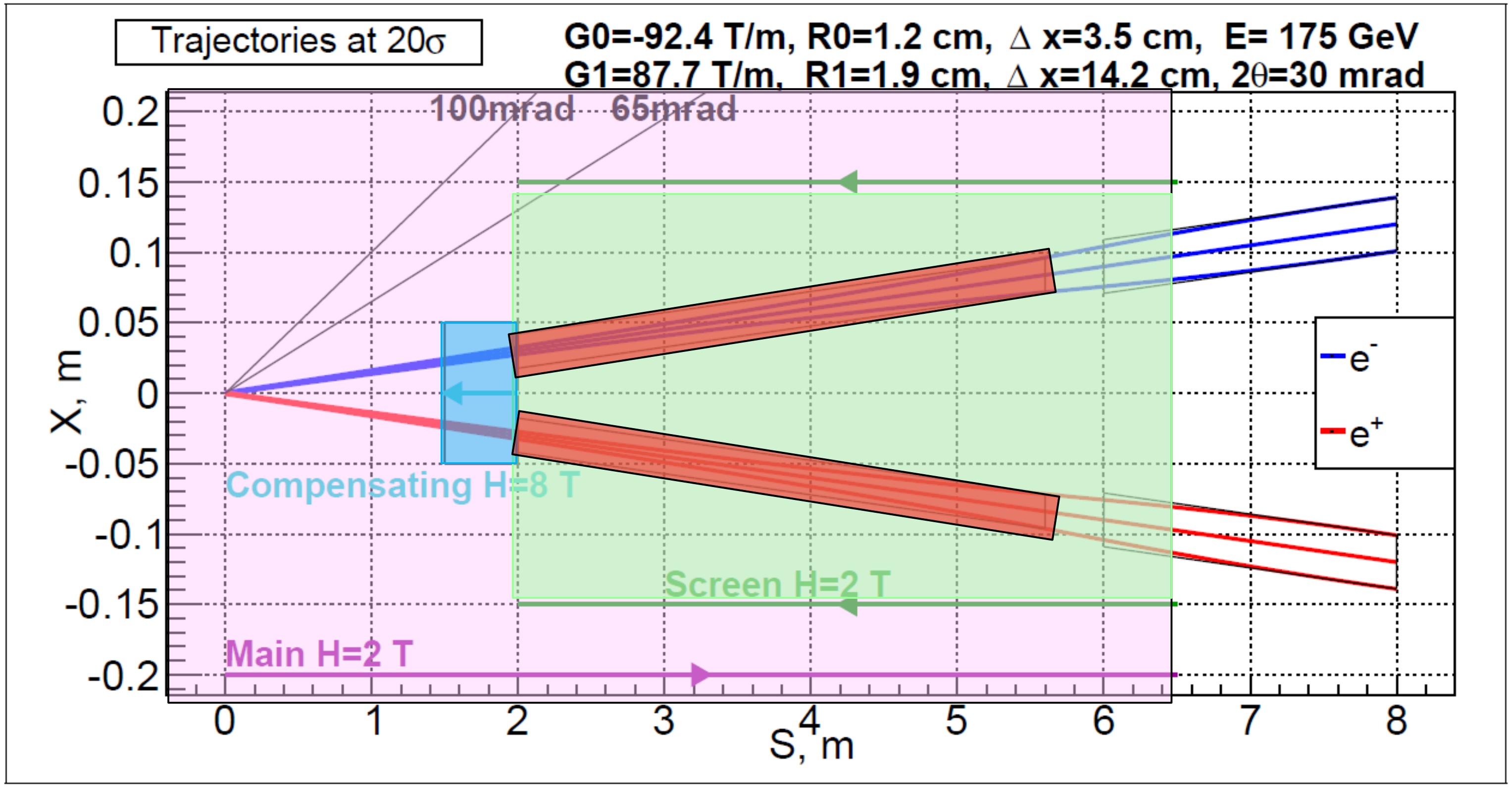
…Questions we should be asking

A PRIMER FOR NON-EXPERTS

Preamble

- The IR layout of FCC-ee is probably the most challenging aspect of the accelerator design
- In particular the IR region around the detector is very complicated due to conflicting requirements:
  - Very aggressive beta* (=1mm)➔The L* of the design is short (=2m)➔ final focus magnets are inside the detector
  - Vertical emittance is very small ~2pm
  - Electrons collide at an angle (currently 30mrad)
  - These f.f. magnets need to be shielded from the main detector solenoid to avoid loss of luminosity
  - For any residual solenoidal field remaining, an anti-solenoid should undo its effect otherwise emittance blows up and polarization suffers.

IR region around the detector: main, compensating and screening solenoids



Final quads

Main detector solenoid

Quad screening solenoid

Compensating solenoid

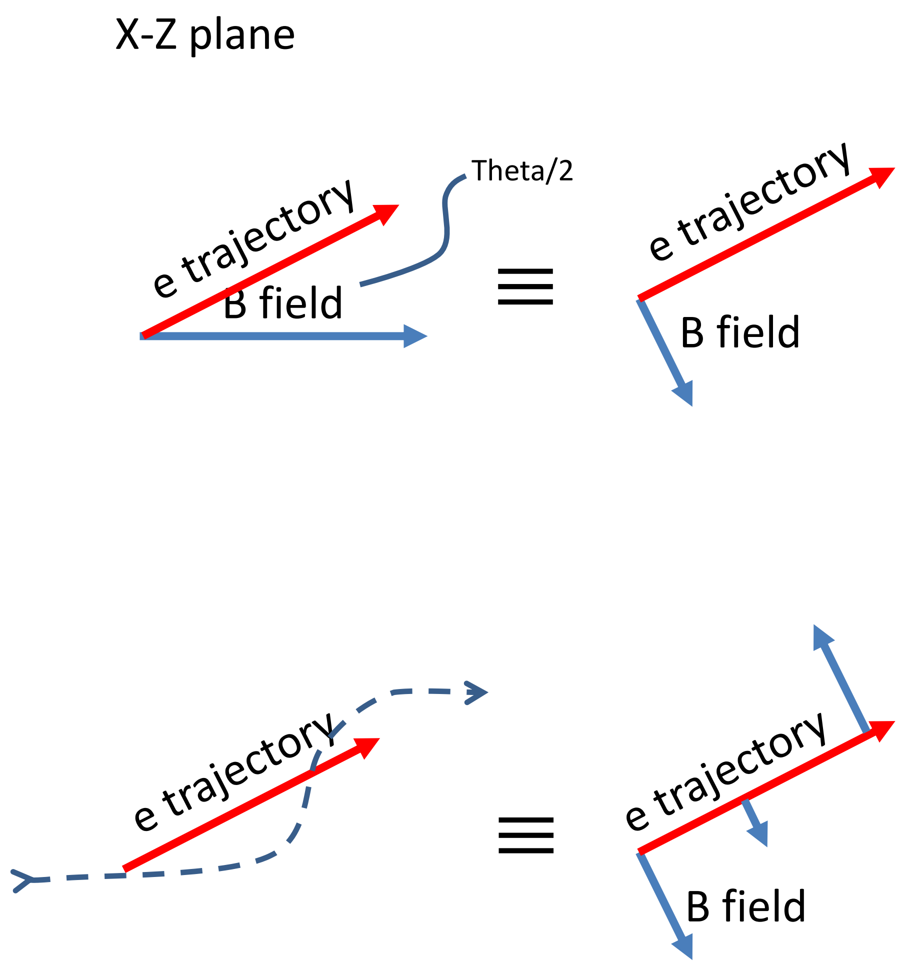
An artist's impression

Effects on polarization

- Polarization is needed for Z and W running
- Solenoids were compensated at LEP, so the knowhow exists (of course complexity is added!)
- I will not discuss polarization issues further here

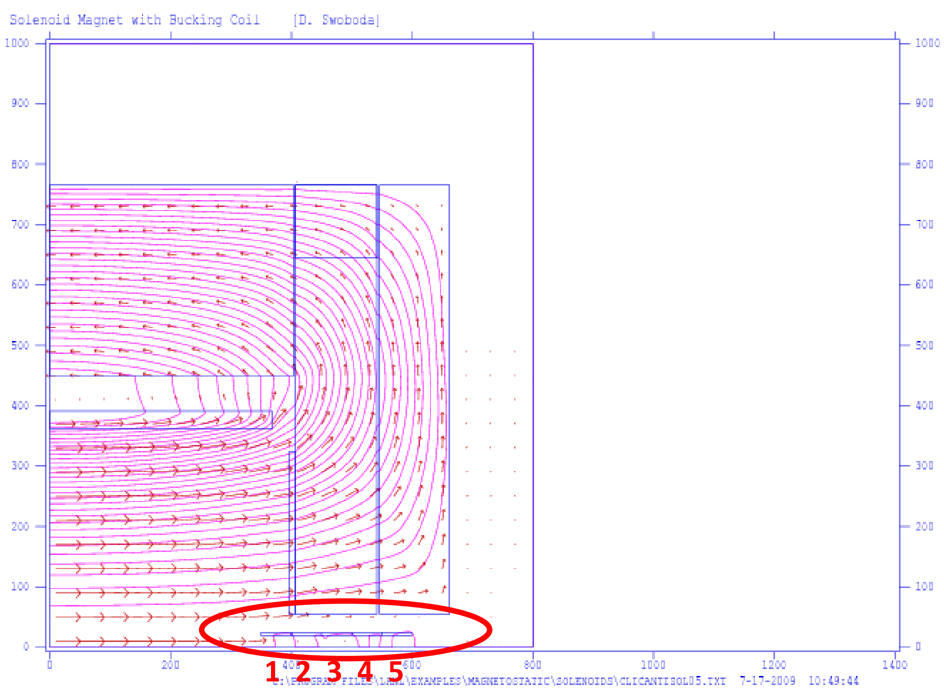
The two components of the problem

- We are bothered by field components that can give a vertical kick (giving rise to vertical emittance)
- The components that give a vertical kick are:
  - B_z*sin(theta/2): this term will always be there if there is a solenoid and a crossing angle
  - B_x*cos(theta/2): this term depends on the size of the fringe fields (their horizontal component)
- For B= 2T, BX=0.4T, theta/2=15mrad and for a typical CW design:
  - First component $\propto$ 0.03 (effect of xsing angle)
  - Second component $\propto$ 0.4 this is 10 times bigger (effect of fringe fields)
- Therefore, we need to worry about fringe fields more than we need to worry about the crossing angle



Get inspiration from CLIC

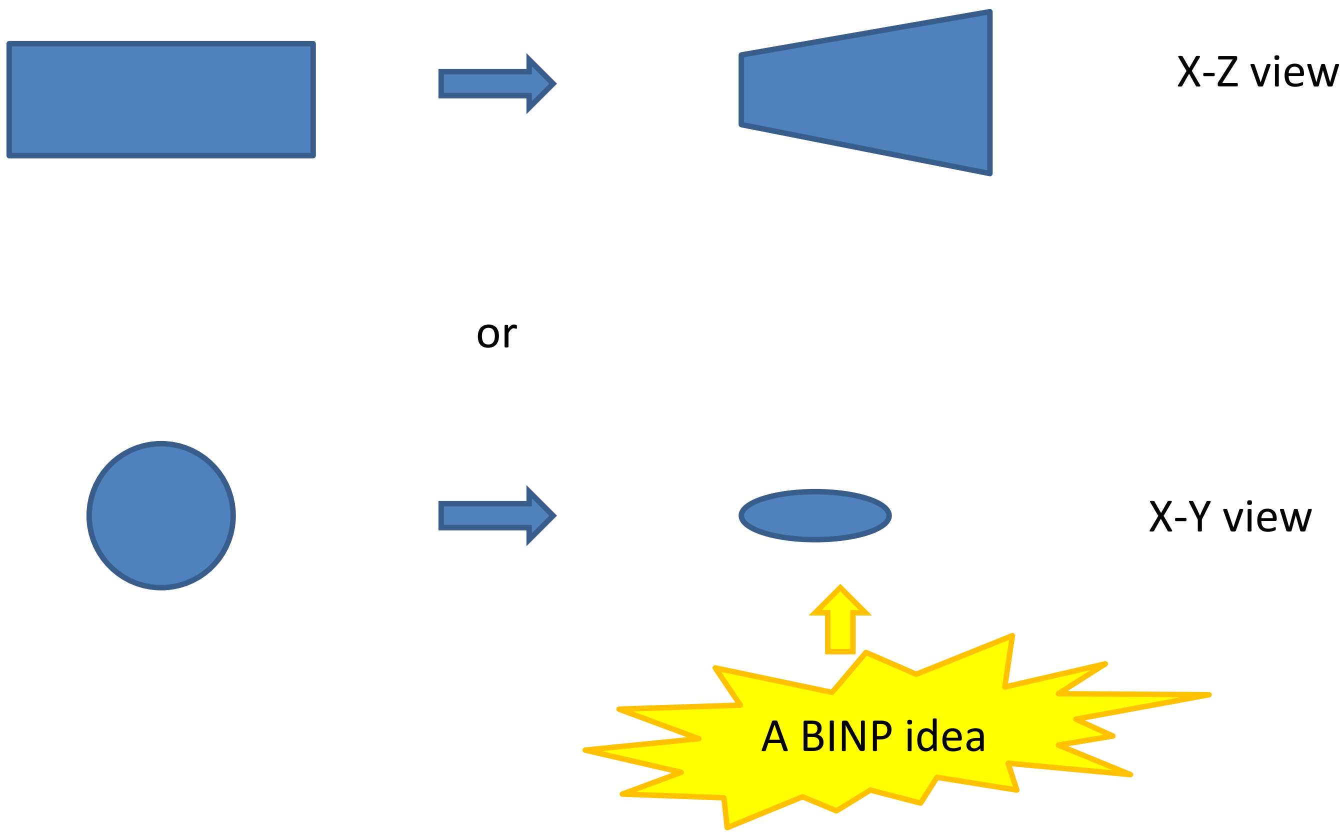
- Splitting the compensating solenoid/anti solenoid in different individually powered pieces gives us substantial flexibility.
- For instance: “bucking” coils @ CLIC



Coil	Current [MA]
Main	16.00
Buck 1 @ 350cm	-1.65
Buck 2 @ 400 cm	-0.72
Buck 3 @ 450 cm	-0.52
Buck 4 @ 500 cm	-0.30
Buck 5 @ 550 cm	-0.15

…be creative

- The solenoid(s) do not need to be perfect cylinders: Same effect can presumably be had by choosing an unconventional solenoid geometry…



The elliptical solenoid idea

- A BINP idea – will be discussed in Anton's talk
- Reduces the vertical emittance by something like (aspect ratio)^5
- But be careful with mechanical integrity problems

Other issues

- Having the anti-solenoid after the DQ0 reduces the fridge fields, but introduces more effects – compensating should take place as close to the source as possible
- The strength of the anti solenoid is currently rather large (8T) but is rather short (50cm) – optimise length vs field strength
- Increasing the crossing angle:
  - Makes the effect worse but
  - Increases separation of quadrupoles and might allow for individual designs of the two final quads (not a common one)
- Would very small individual anti-solenoids be possible?

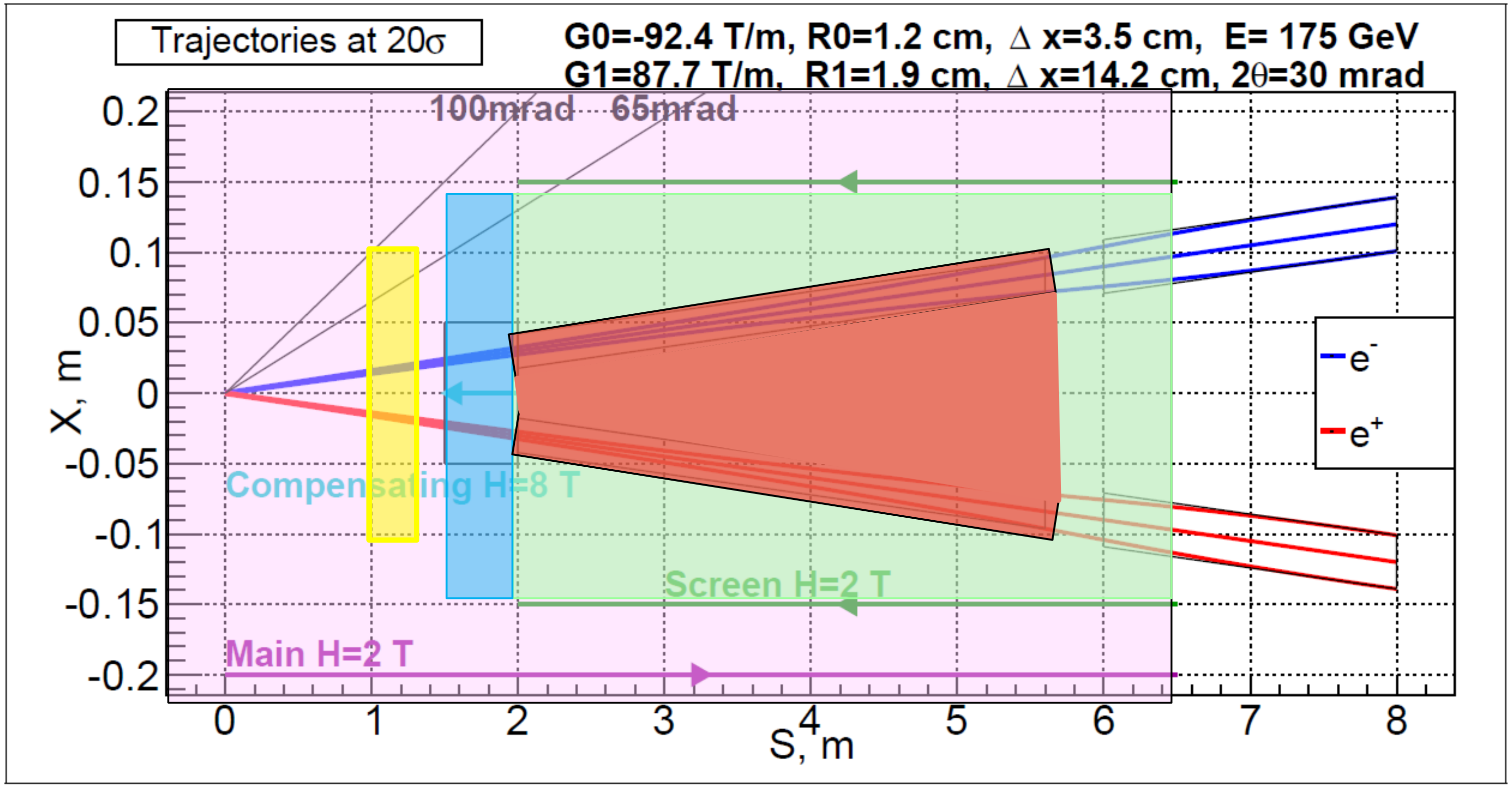
Where do luminometers go?

- The cone <100mrad is in the jurisdiction of the machine, whereas >100mrad of the experiment
- The luminometers can go to either region.
- Can at least the relative luminosity monitor fit inside the anti-solenoid? (in case of a solution *a la* Delphi)

Possible layout geometry

- …pick up your favourite

‘baseline’



Final quads

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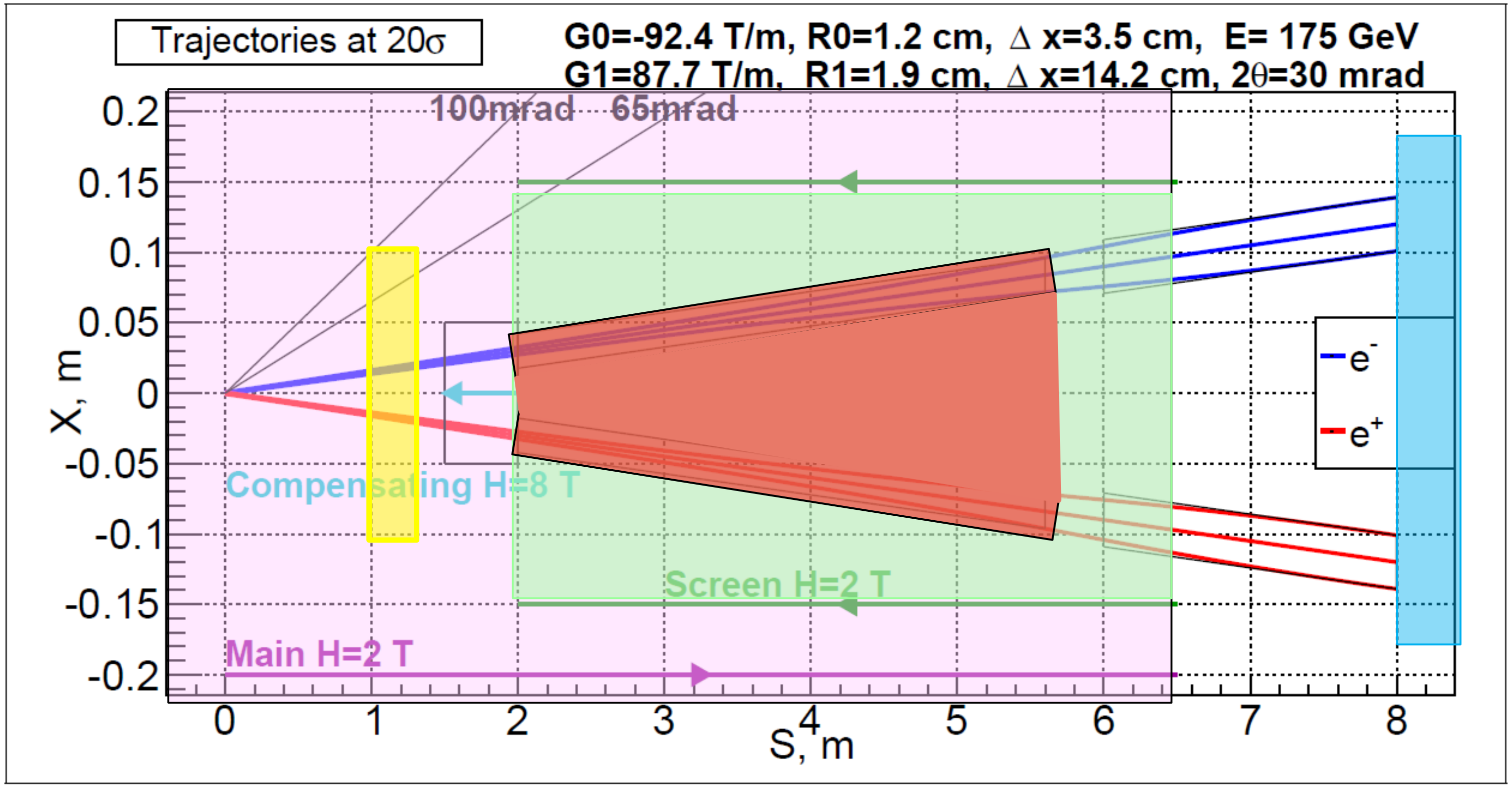
Compensating solenoid

Luminosity counter

Moving compensating solenoid downstream



Final quads

Main detector solenoid

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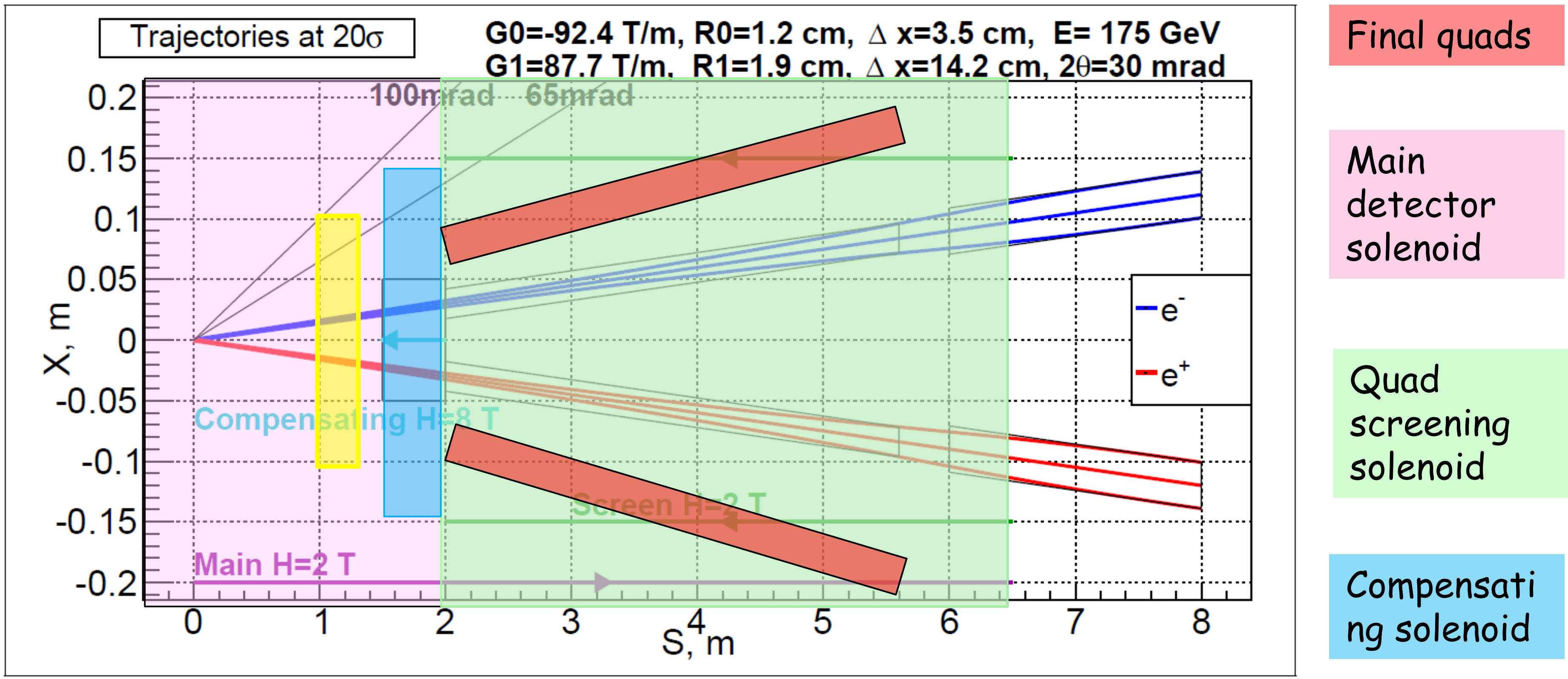
Luminosity counter

Downside: compensation not as performant

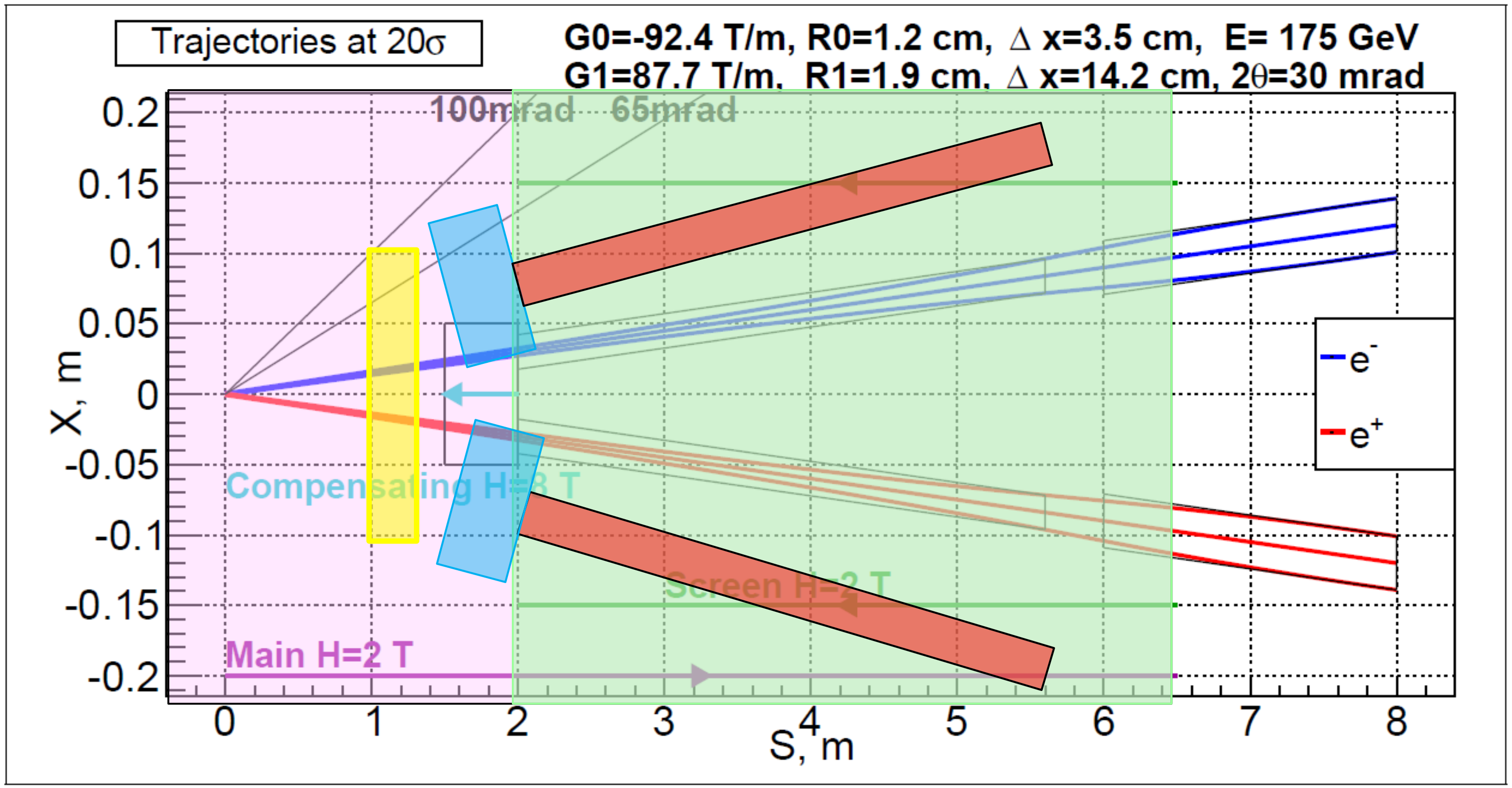
Higher crossing angle



Upside: quad design easier

Downside: more compensation needed for sin(theta)

Higher crossing angle II



Final quads

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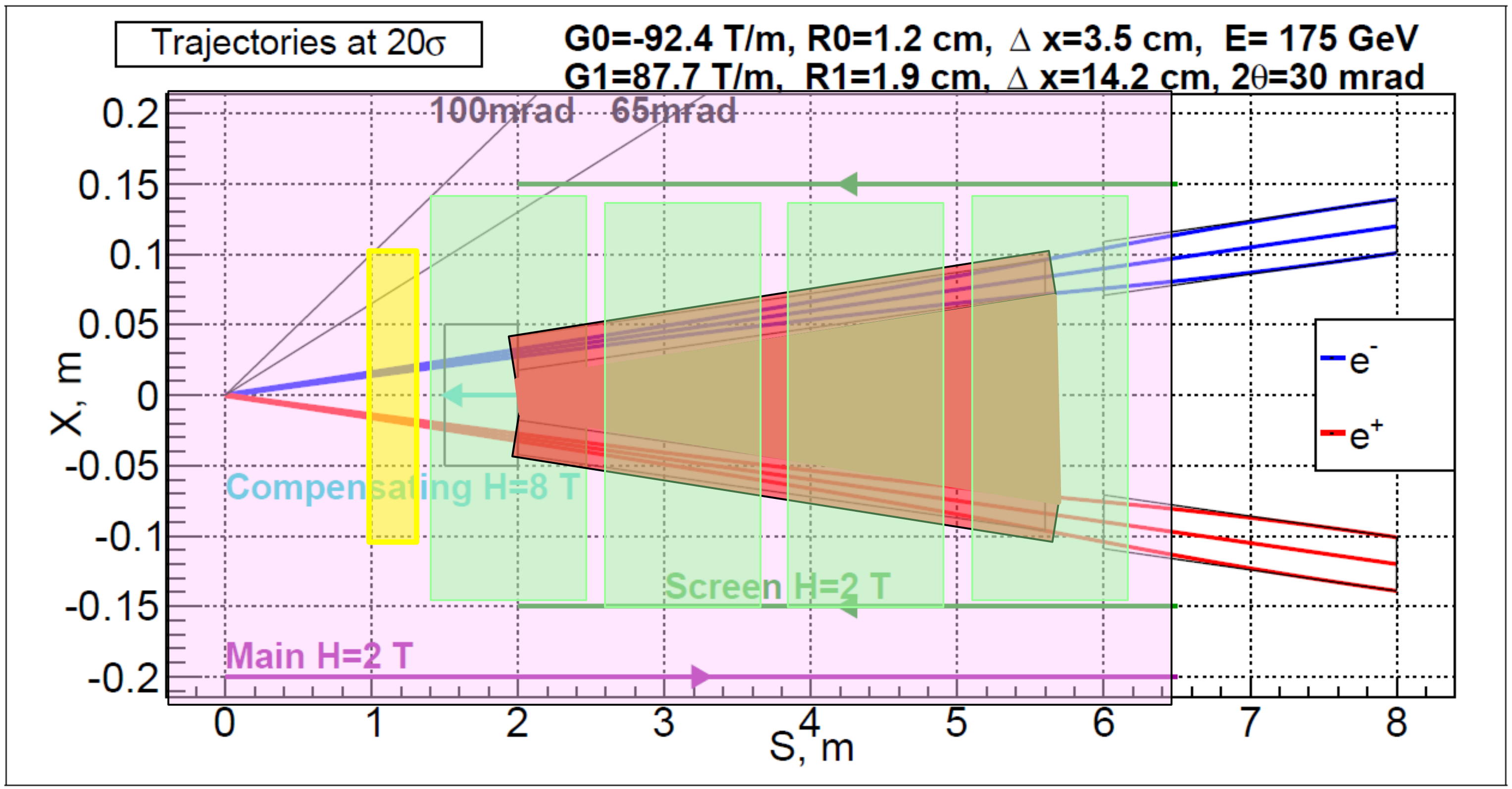
Luminosity counter

Individually powered compensation coils 'bucking coils'



Final quads

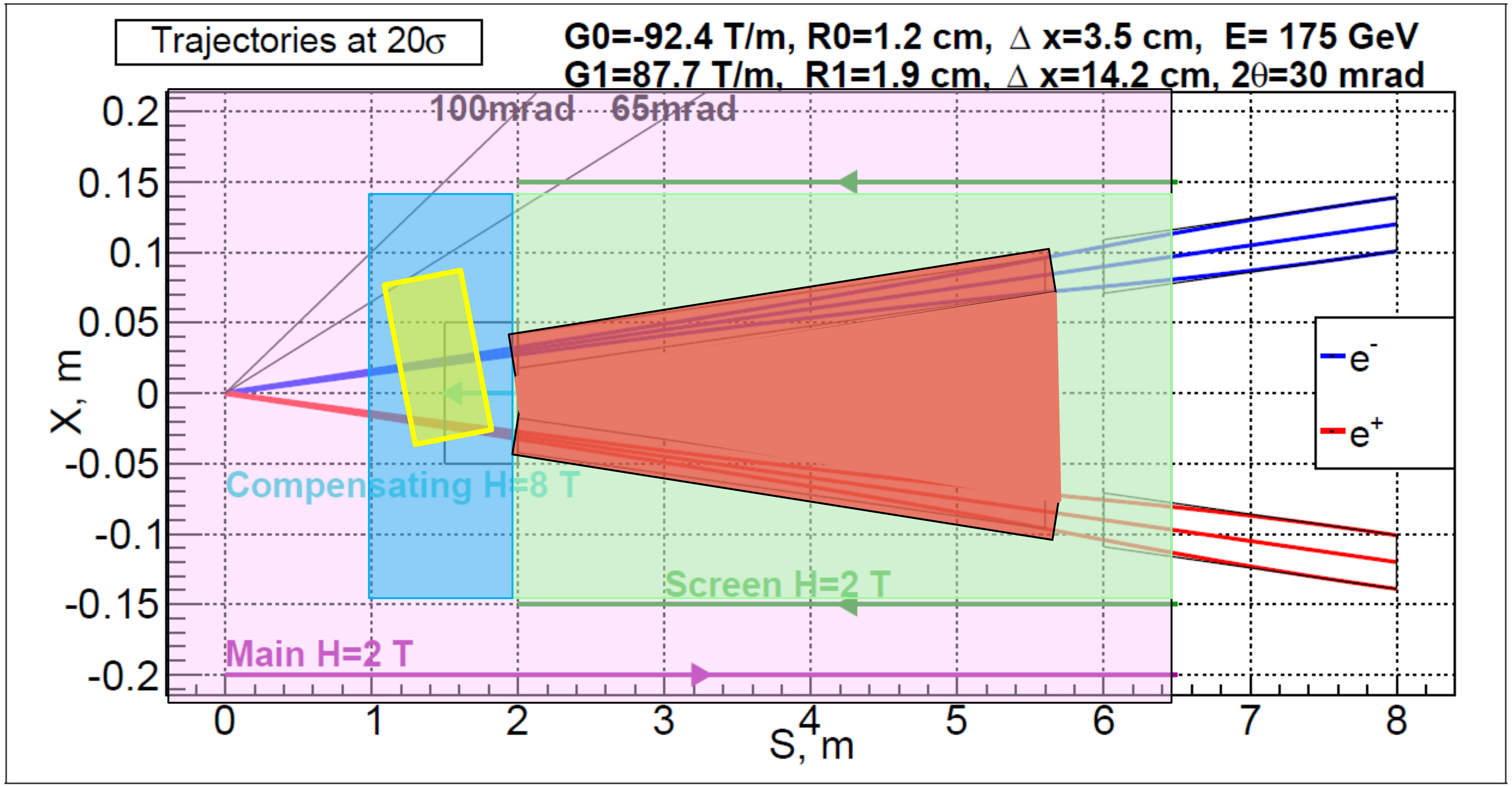
Main detector solenoid

Bucking coils

Luminosity counter

Upside: more flexibility; screening solenoid and compensating solenoid distinction murky

Luminosity counter inside a longer and weaker compensating coil



Final quads

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Luminosity counter

Conclusions

- Possibilities are (nearly) endless: a perfect situation
- We should concentrate in a design that does not blow up the vertical emittance more than ~1pm
- The elliptical solenoid idea looks promising (almost too good to be true)
- A series of individually powered coils or a unconventional geometry might give us more flexibility (if we need it)
- Many more ideas should be explored (individual solenoids, etc.)
- Once we have a baseline design, a basic magnet design should be performed