Combined Function Magnets/Calorimeters

- Introduction
- Superconducting magcal concept
- Geant4 studies
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  - Liverpool
- Summary

Insertion of GO magnet into H1 detector

Introduction

- Luminosity at colliding beam experiment given by:

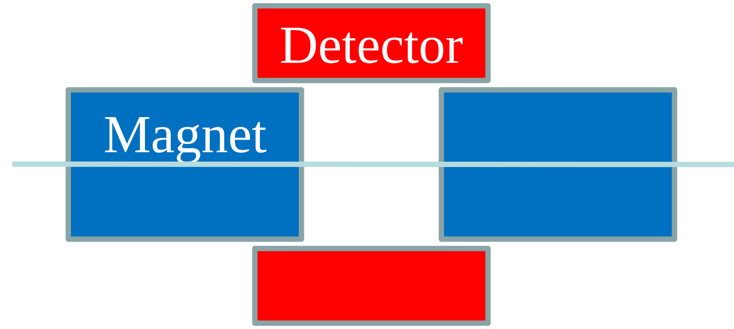
$$\mathcal{L} = f \frac{N_1 N_2}{4\pi\sigma_x\sigma_y}.$$

- Highest $\mathcal{L}$ therefore requires smallest area for collisions.
- Near interaction point (L = 0):

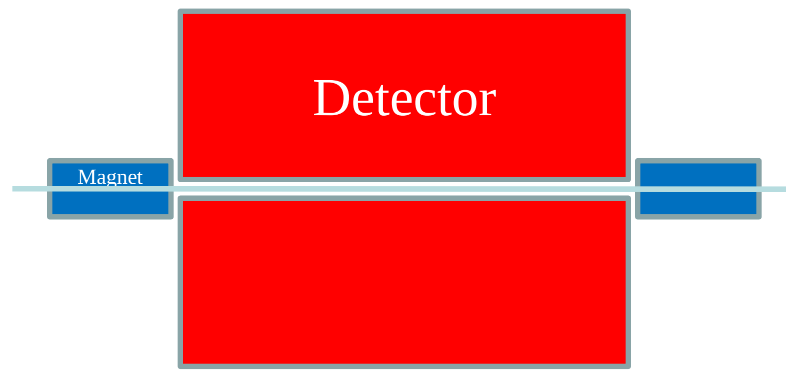
$$\sigma_{x,y} = \sqrt{\varepsilon_{x,y}\left(\beta^*_{x,y} + \frac{L^2}{\beta^*_{x,y}}\right)}.$$

- Need accelerator magnets as close to IP as possible.
- Not compatible with largest detector acceptance.

- Maximum luminosity.



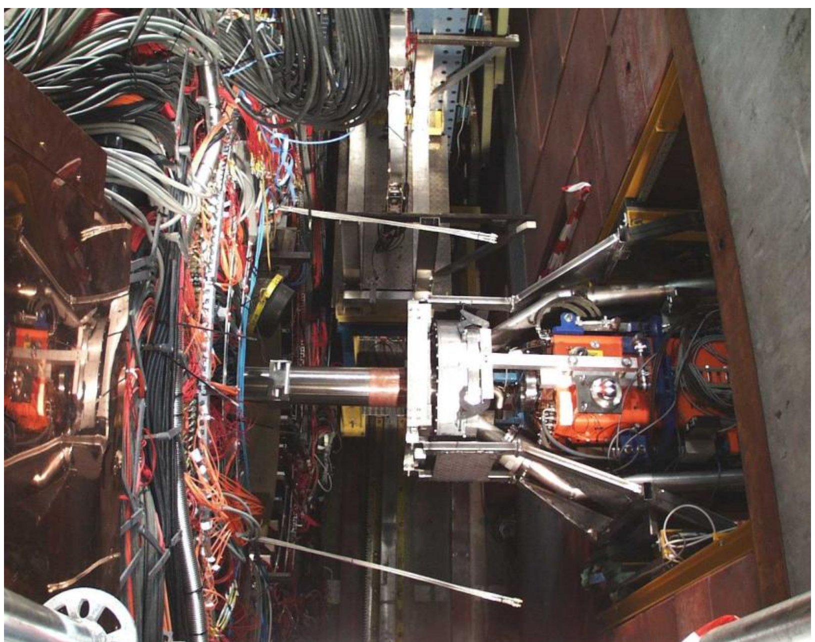
- Maximum experimental acceptance.



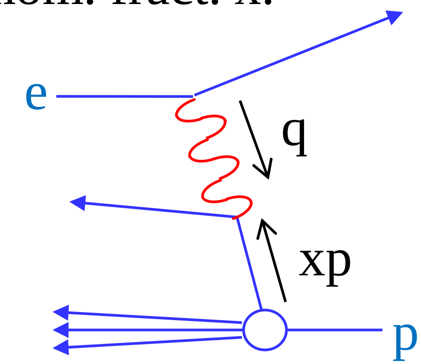
- Make magnets also detectors?

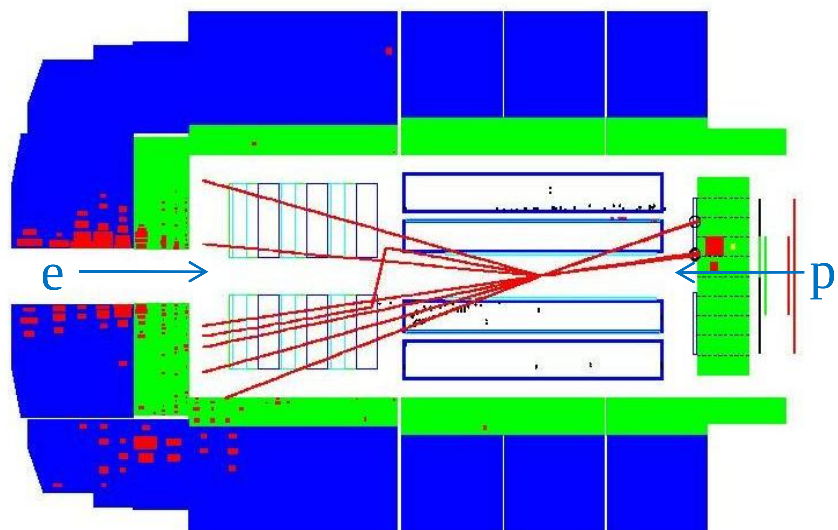
Introduction

- An example, upgrade of HERA electron-proton collider resulted in $\mathcal{L}$ increase of factor ~ 5, but significant loss of experimental acceptance.
- Illustrated here for H1 detector.



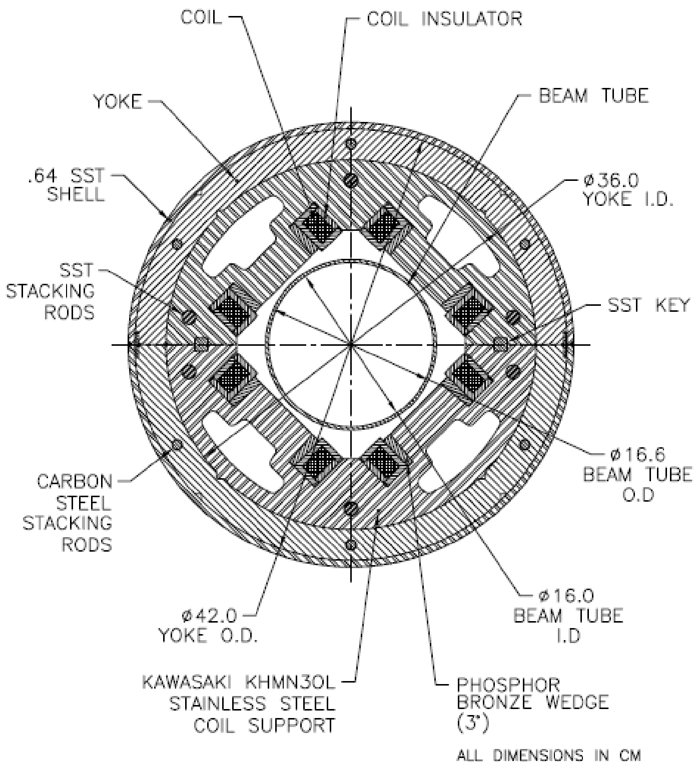
- Resolution $Q^2 = -q^2$.
- Proton mom. fract. x.

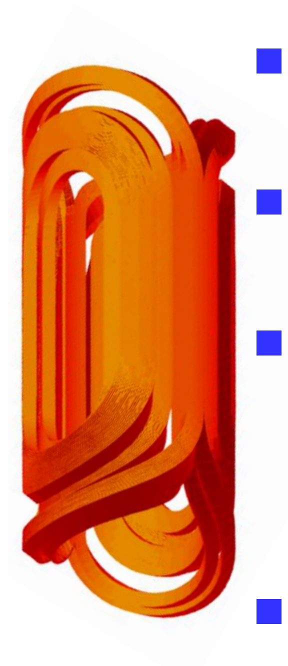




Superconducting magcal – conceptual design

- Magnet coils in He bath.

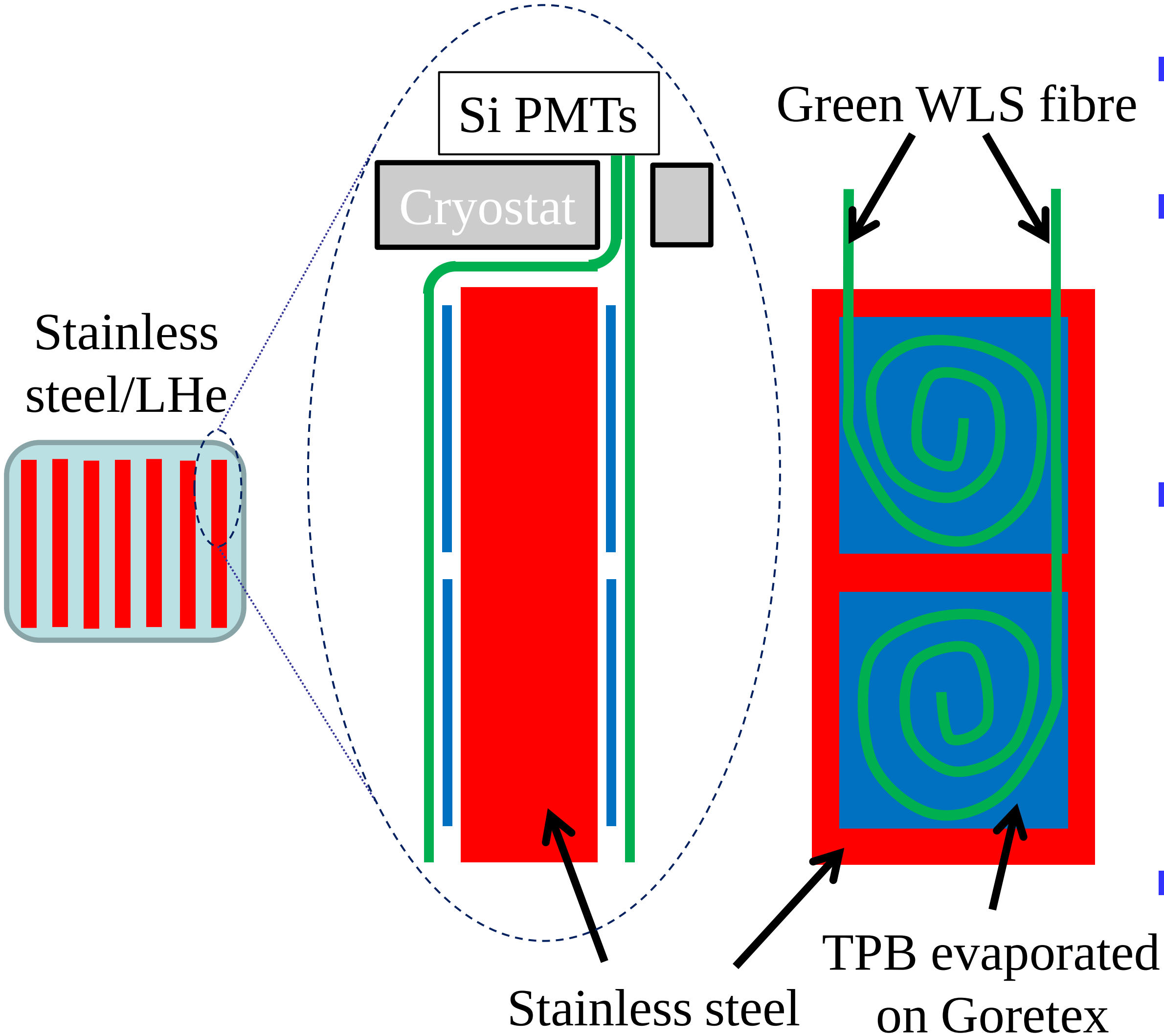




- Make calorimeter with LHe as active component?
- Ionisation signal not useable.

- LHe efficient scintillator, emits ultra-violet light (λ ~ 80 nm)
- 35% of energy lost by relativistic e^- emitted as light within ~ 1 ns.
- Mechanism: ion-electron pairs plus excited atoms formed.
- Ions attract ground state atoms, excited atoms combine with ground state atoms, both form excited diatomic molecules.
- Diatomic molecules decay to ground state atoms emitting light.
- Energy of light lower than gap between ground and first excited state, so little re-absorption.

SC magcal – conceptual design



- Possible design stainless steel/LHe sandwich.
- 2 mm thick steel plates with similar width gaps:
  - X_0 ~ 2 cm.
  - λ_I ~ 20 cm.
- Use fluor tetraphenyl betadiene (TPB) to absorb scintillation light and re-emit in blue (λ ~ 430 nm) – with efficiency 135%.
- (Using LHe as a scintillator is being considered for e.g. solar neutrino experiments.)

SC magcal – conceptual design

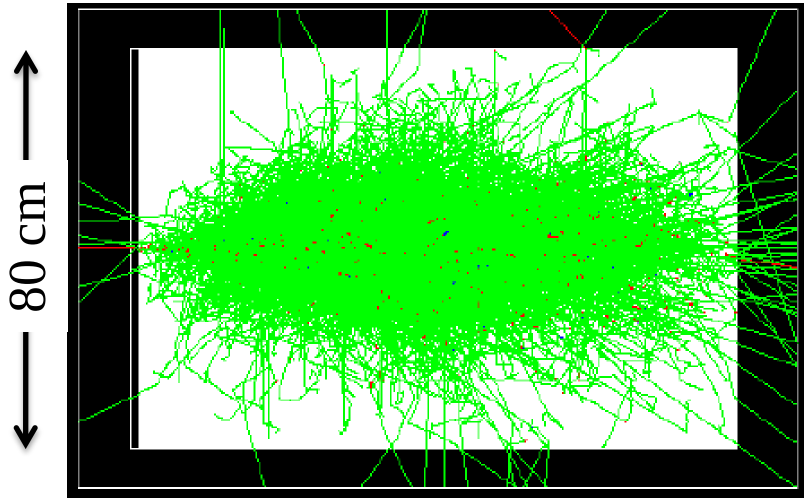
- Given time constants of fast LHe scintillation, TPB and WLS fibre, expect signal within ~ 20...30 ns.
- Minimum ionising particle loses ~ 50 keV in 2 mm of LHe.
- Produces ~ 3000 photons.
- Systems tested for monitoring low energy solar ν flux have ε ~ 0.1% (photons to photoelectrons) with conventional photomultiplier.
- Gives usable signal from energetic showers.

- Can very probably significantly improve optics:
  - Replace conventional PMs with Si PM, ε_{chain} ~ 0.4%.
  - (Blue) photons trapped in TPB layer can be extracted more efficiently by careful design of layer:

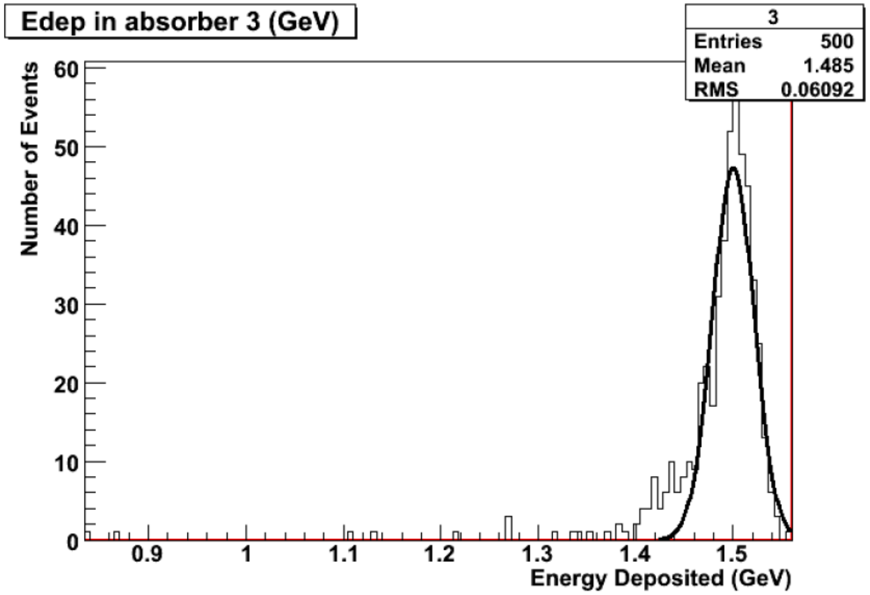
  - Alternatively, use fibre attached to edge of layer.

Geant 4 studies Birmingham

- Study of behaviour of stainless steel/LHe calorimeter (Tony Price, Paul Newman, Paul Thompson).
- Transverse size 40 cm adequate for containment of electrons showers of energies 10...100 GeV.
- E.g. of 70 GeV e^- shower in 200 layers of 2 mm SS/4 mm LHe Calo.



- Histogram of energy deposited in LHe by 100 GeV electron:



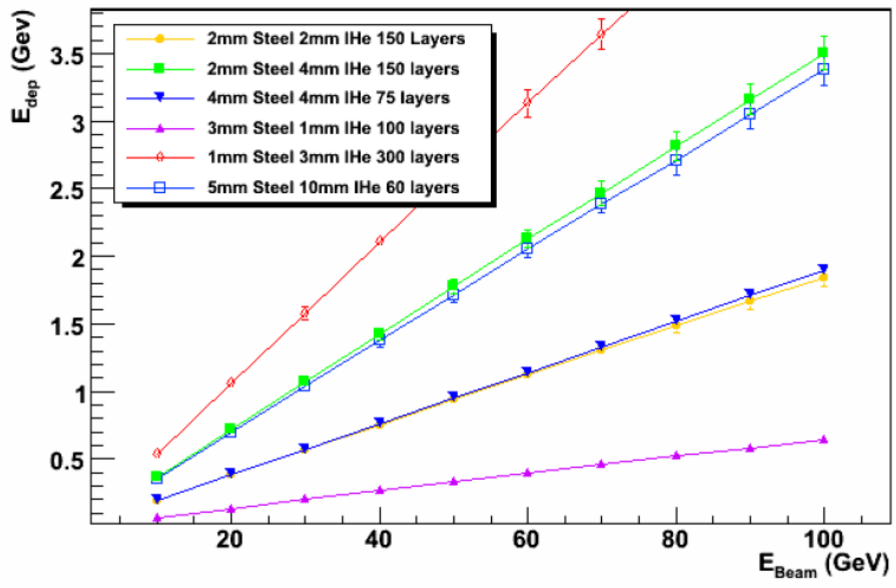
- Mean and RMS calculated from gaussian fit in range $-\sigma$ to $+ 2\sigma$.

Geant 4 studies Birmingham

- Investigate energy deposited in and resolution achievable with various sandwich structures:

Steel (mm)	LHe (mm)	No. layers
2	2	150
2	4	150
4	4	75
3	1	100
1	3	300
5	10	60

- Energy deposited in LHe for these structures:



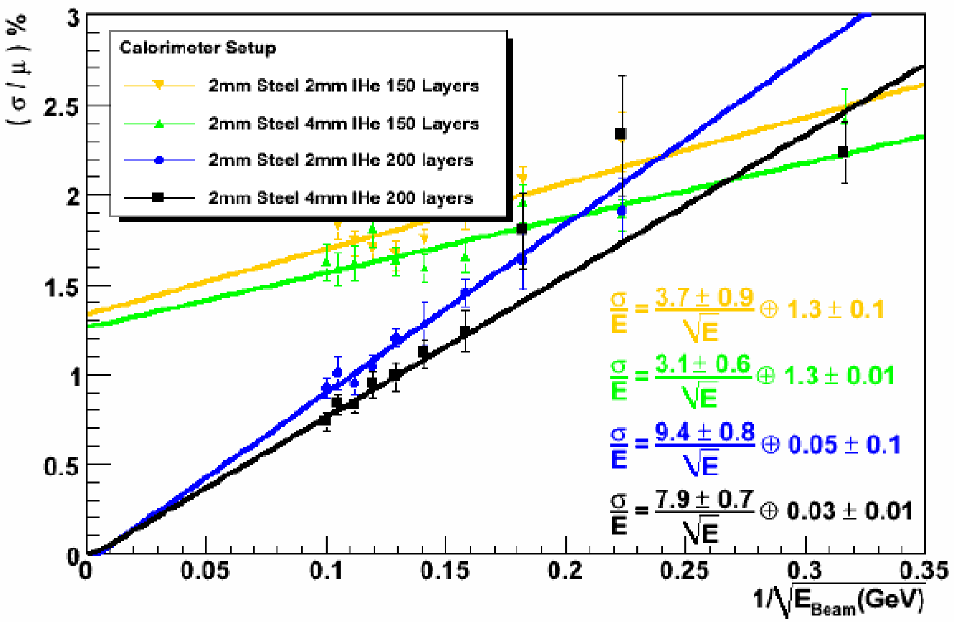
- Good linearity in all cases.
- Energy in LHe dependent on LHe fraction, as expected.

Geant 4 studies Birmingham

- Resolution, expect:

$$\frac{\sigma}{\mu} = \frac{\text{const.}}{\sqrt{E}}.$$

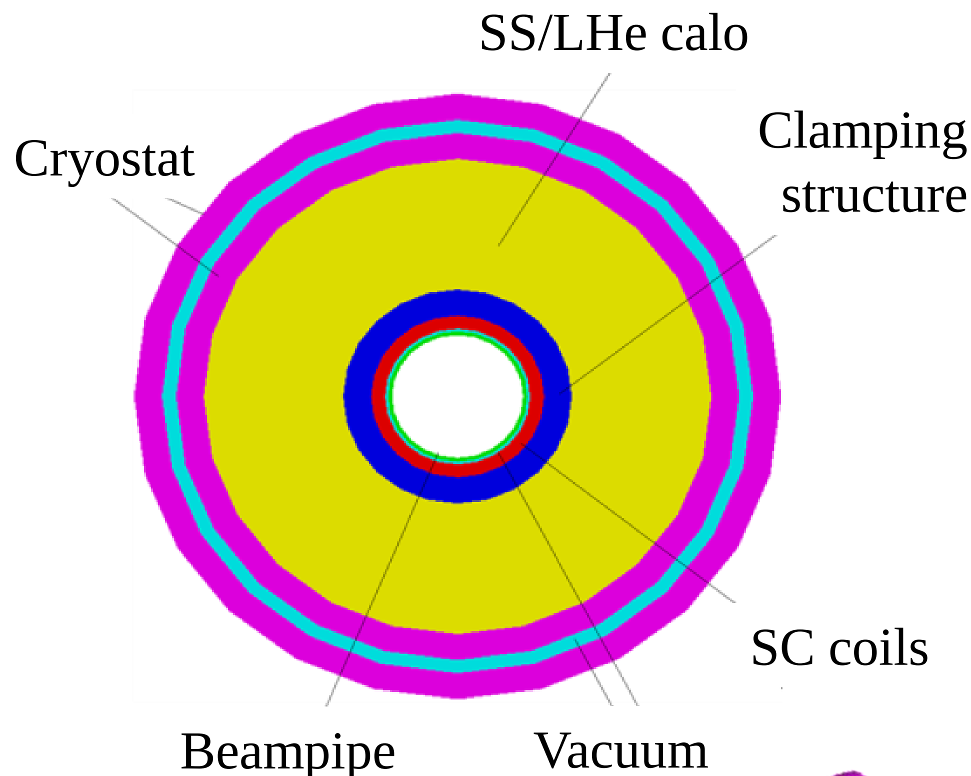
- Extract const. from slope of graph of σ/μ against $1/\sqrt{E}$.

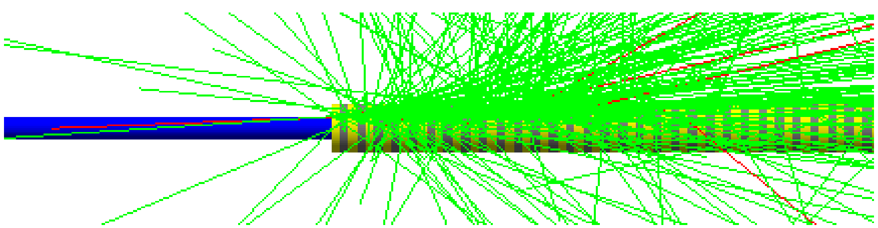


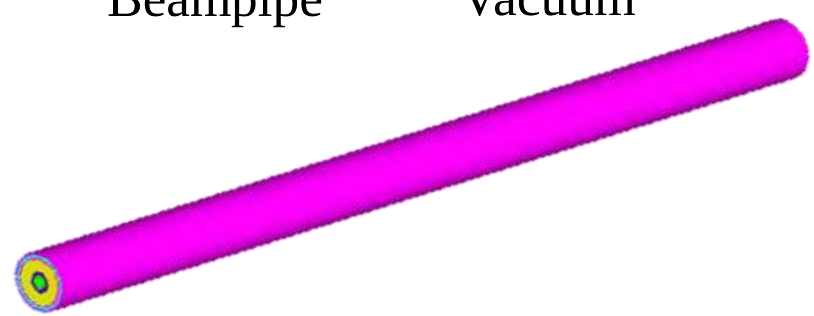
- Note, depth of 150 layers (about 17 X_0) leads to leakage, hence positive intercept on y axis, 200 layers (23 X_0) gives better performance.
- Resolution of order $0.1/\sqrt{E}$ achievable according to these simulations.
- Adding material associated with readout of scintillation light (here polystyrene assumed) does not significantly change this result.
- First studies with B field indicate broadening of shower.

Geant 4 studies Liverpool

- Information on SC magnets from Davide Tommasini, assumed B fields: dipole ~ 3 T; quadrupole ~ 100 T/m.
- Build Geant4 model of Magcal (Natasha Bintley, Jordan Denton, John McGrath).
- Calo. with SS 4 mm, LHe 4 mm, used to investigate measurement of electrons with energies in range 10...60 GeV.



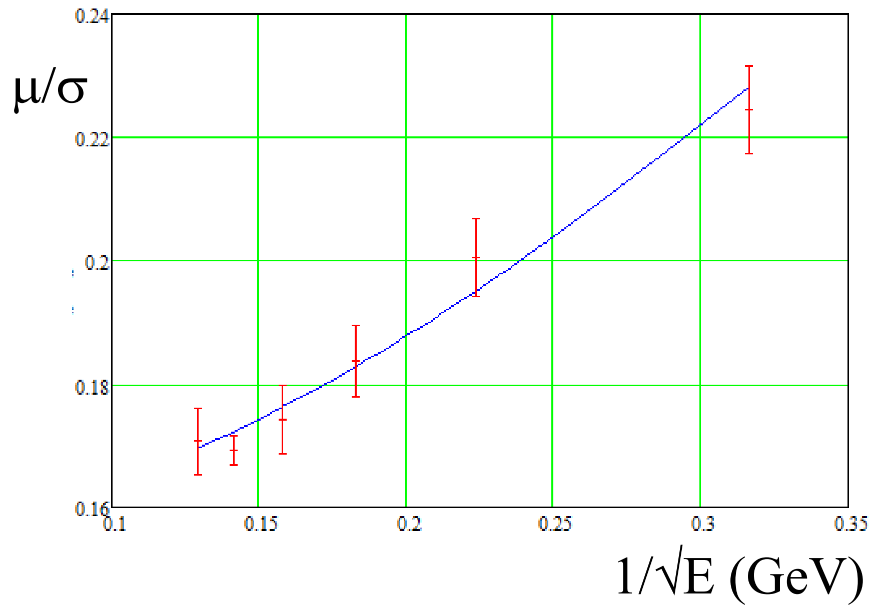




Geant 4 studies Liverpool

- Preliminary results:
- The good news:
- If sensitive radius ~ 6...46 cm, e^- impact far from edge, resolution compatible with previous results.
- The bad news:
- If decrease size of sensitive region and/or e^- impacts at edge of sensitive region, resolution deteriorates, leakage significant.
- Large impact position dependent corrections needed.
- Showers broad, so impact position must be provided by tracking device in front of Magcal.

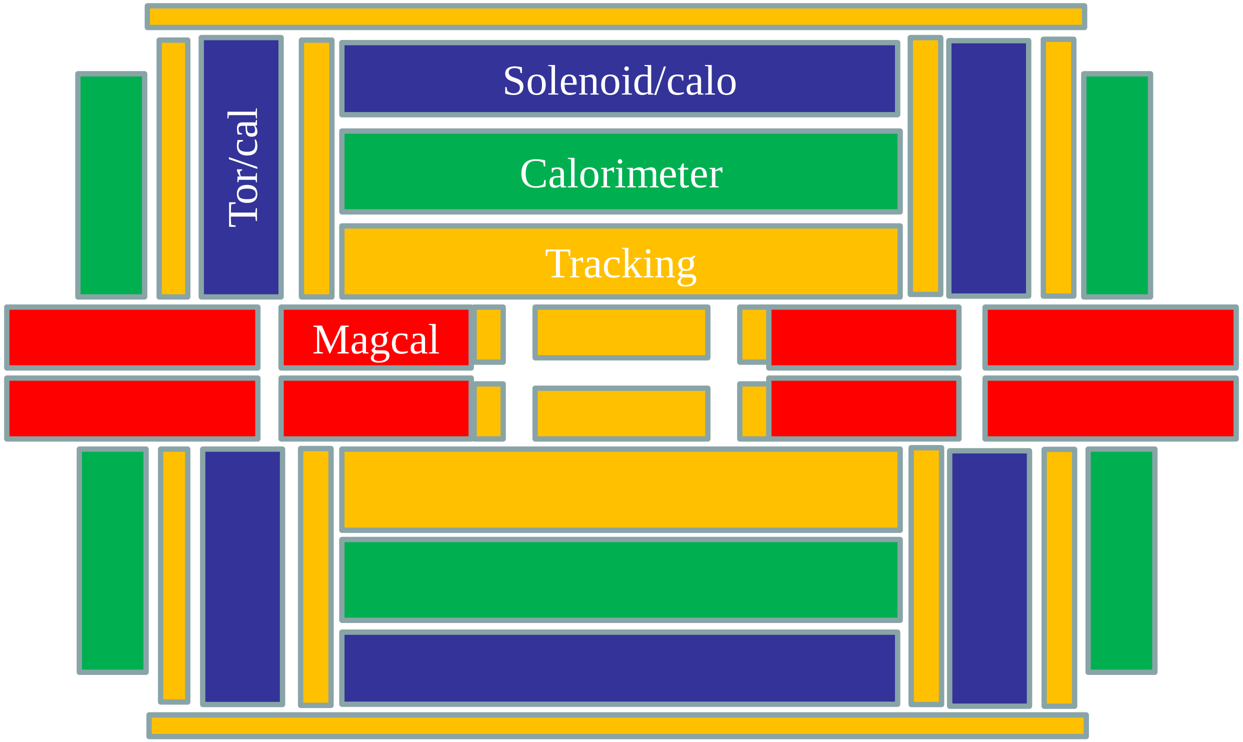
- E.g. electrons impacting at angle of 2° at edge of clamp structure, sensitive region ~ 6...16 cm:



- Resolution ~ 50%/√E.

SC magcal – possible uses at LHeC?

- As machine magnets closest to IP:
  - Implies minimum radius of sensitive region about 6 cm.
  - C.f. closest possible "normal" Calo. at about 16 cm.
- As detector magnets?
- No work on use as solenoid and/or toroids as yet!



Summary

- Highest luminosity at collider requires magnets close to IP.
- These limit experimental acceptance unless they can provide (calorimetric) measurements.
- Stainless steel/LHe scintillation sandwich calorimeters look to be able to provide an energy resolution of ~ 10%/√E...
- ...but the showers in the calorimeters are broad and so they have to be reasonably large.
- First studies suggest design choice is between something like:
  - Magcal with outer radius of about 60 cm allowing measurements down to radius of about 6 cm.
  - Magnet with outer radius of about 16 cm (depending on B field requirements) with surrounding "normal" calorimeter.
- Possibility of "active" solenoids and toroids yet to be investigated.