Higgs studies at a future electron-positron collider

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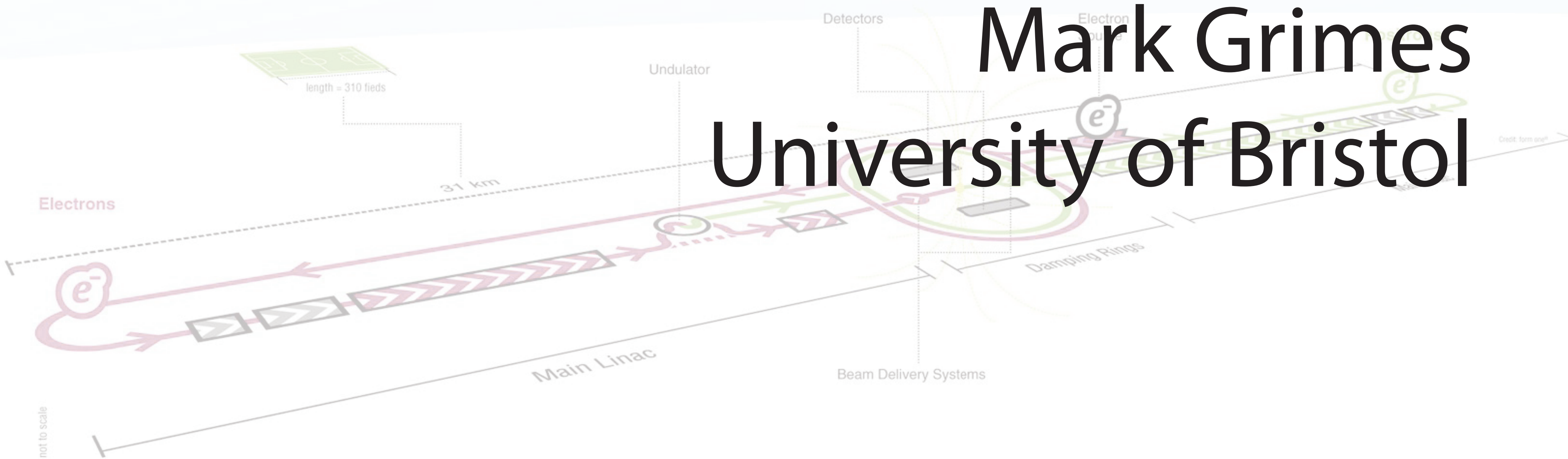

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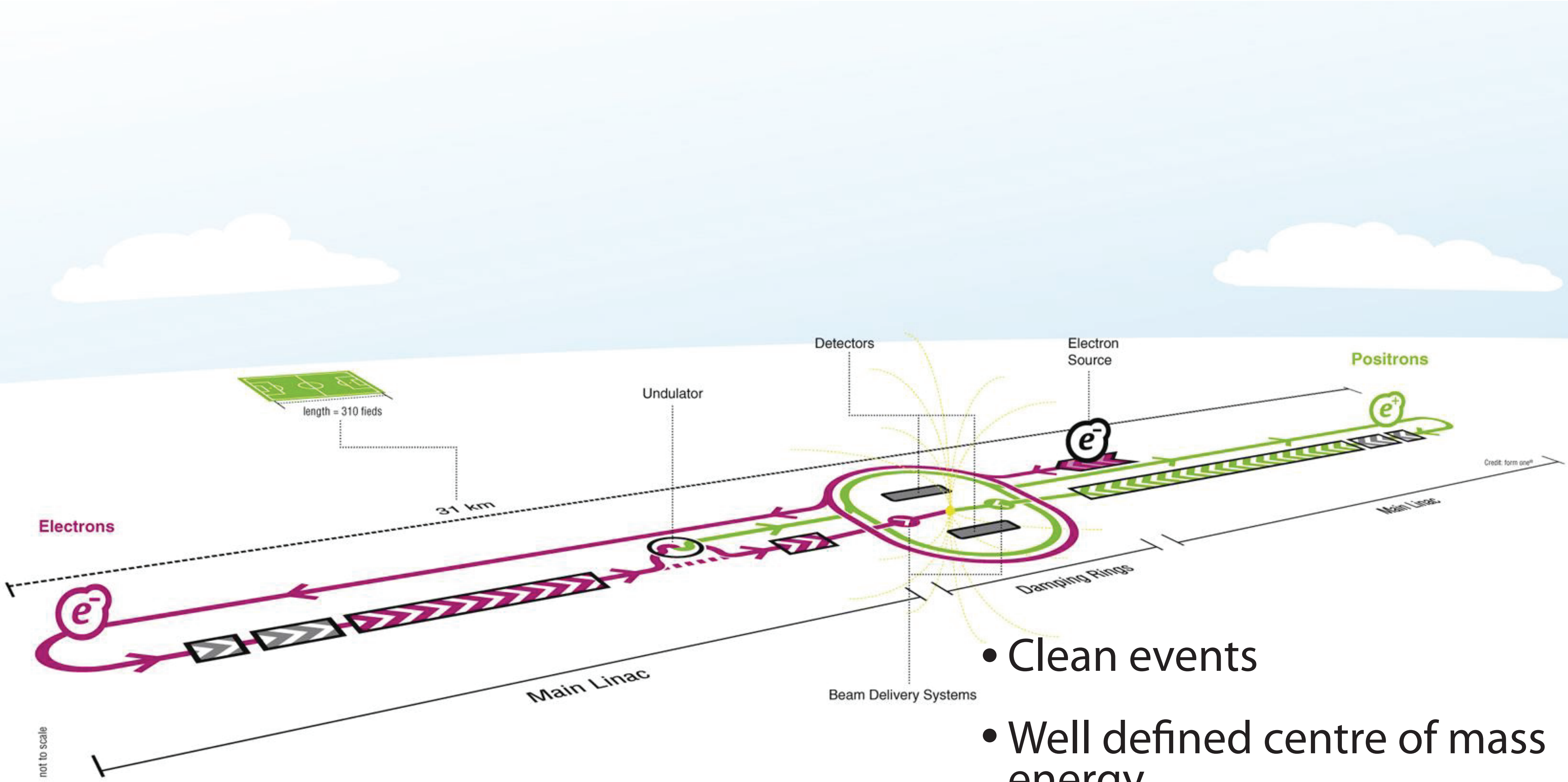
Lepton colliders



- Clean events
- Well defined centre of mass energy
- No triggering required

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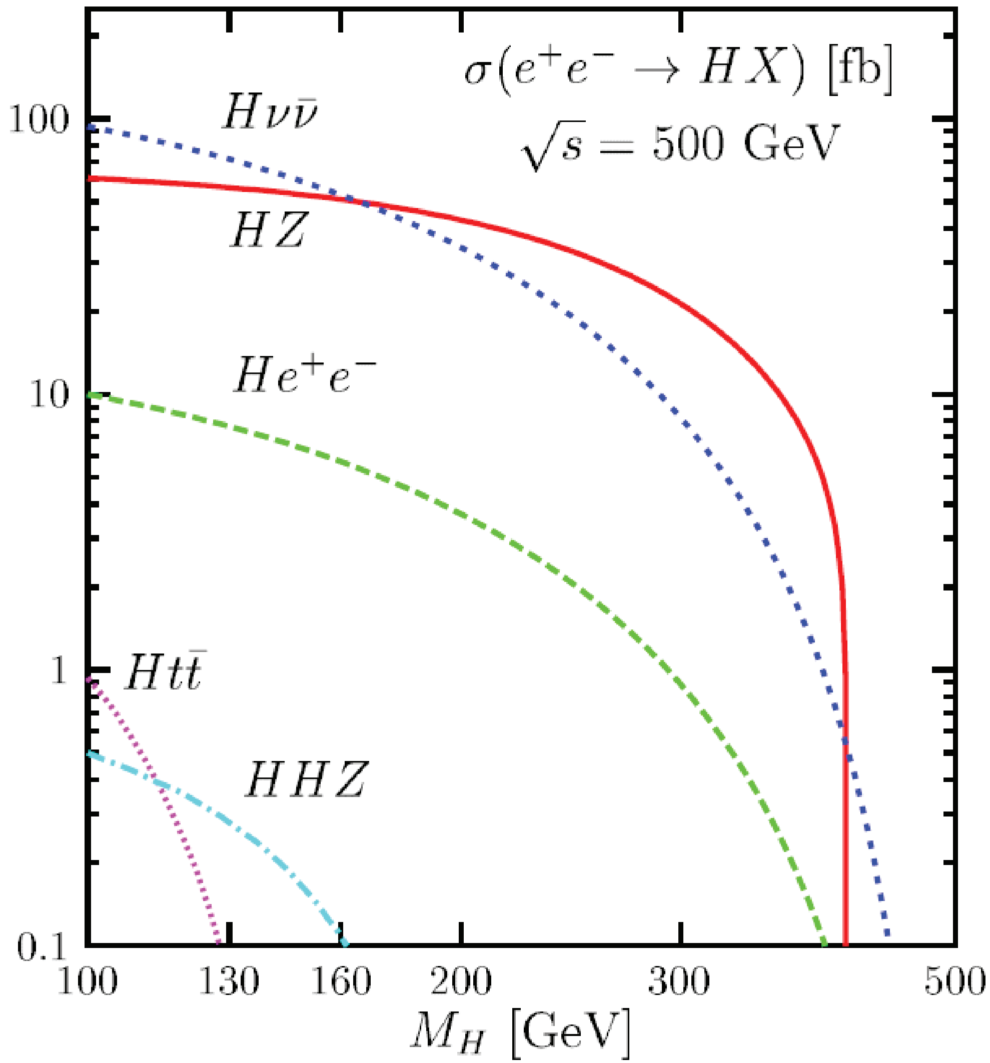
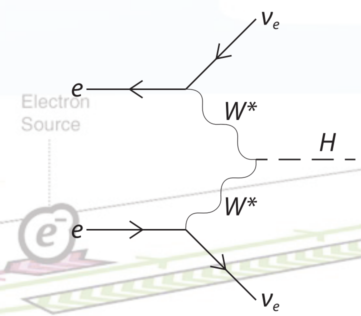
Higgs production at the ILC

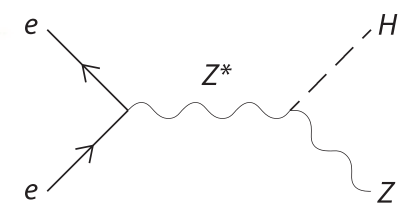


For the 500 fb^{-1} expected in the first 4 years (for 120 GeV Higgs):

~40,000 H$\nu\bar{\nu}$ events



~30,000 ZH events

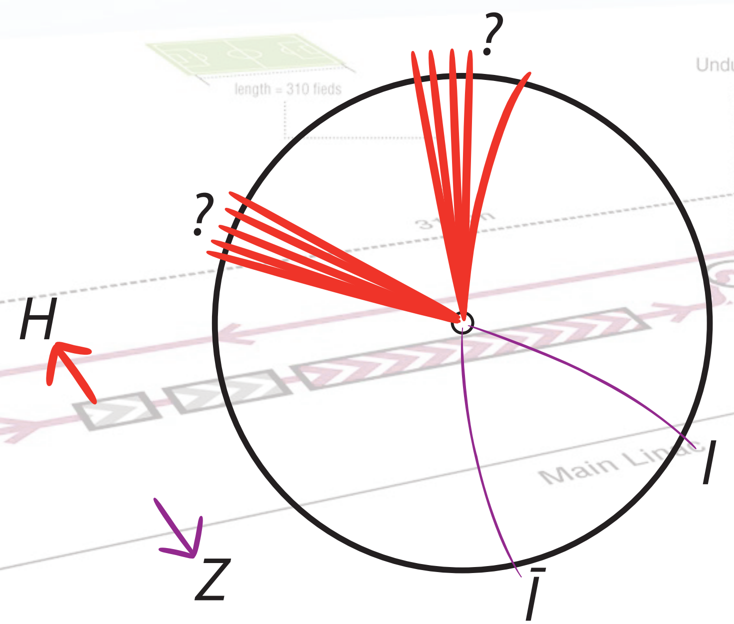


ZH event topology

How will the Z in the ZH events decay?

leptons ~10.4% (~3.4% electrons)
hadrons ~69.9%
invisible ~20%

Z to leptons is considered “the golden channel”



The electrons should be clearly separated and easily identifiable, hence excellent signal separation.

The superior momentum resolution of the tracks should give a better Higgs mass than the jets from the Higgs.

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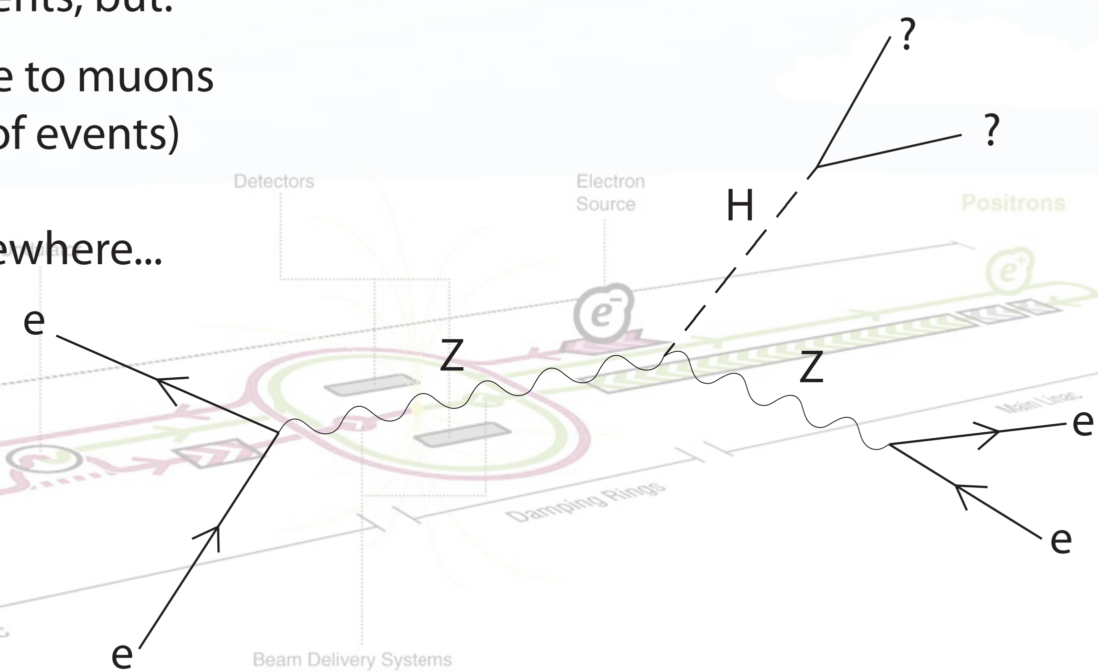
Measuring the Higgs Branching ratios

All of the Z decay channels can be used to measure the branching ratios. Currently concentrating on the electron channel.

only ~3.4% of the ZH events, but:

easily extendable to muons (another ~3.4% of events)

got to start somewhere...



Extending Kuhl and Desch's fast Monte Carlo analysis[1], but with full simulations

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[1] LC-PHSM-2007-002

Event selection

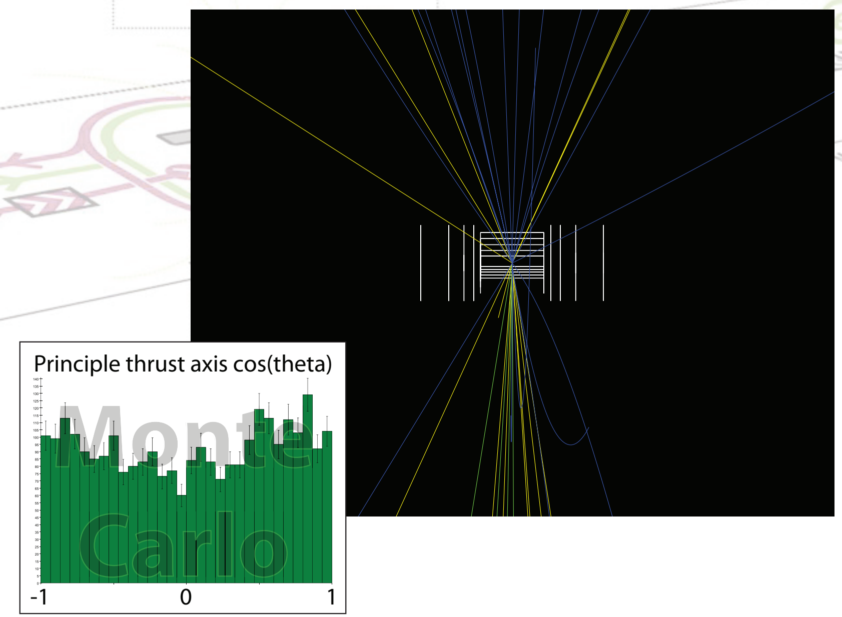
After trivial cuts on the identified leptons (number, invariant mass etcetera), the background is mainly due to Z pairs.

Z pair background is reduced using a likelihood selection on:

- Thrust and Thrust direction - the signal is expected to be produced more centrally and be more spherical
- Invariant mass - The hadron jets should have the Higgs mass
- Jet energy difference - The background is expected to have a larger energy spread because of the boost.

ZZ

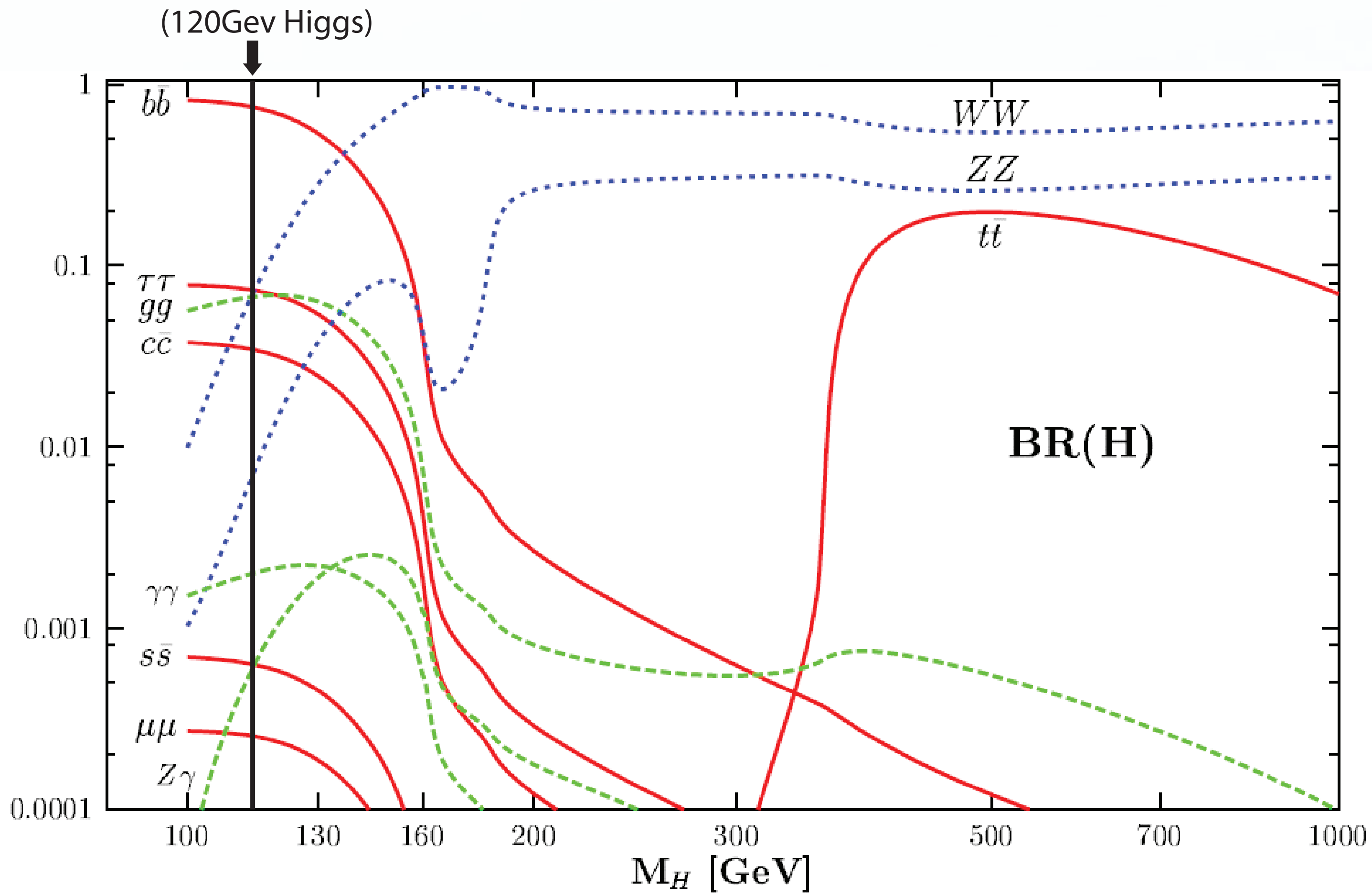
$b\bar{b}$



Event selection

For a light Higgs, the important decay modes are:

bb (~80%)
cc (~4%)
gg (~5%)



...lots of hadron jets, hence need very good flavour tagging.

Flavour Tagging

Currently using the flavour tagging method developed by Richard Hawkings[1]. Neural net based approach; inputs depend heavily on impact parameter resolution -> Vertex detector performance critical.

- Impact parameters for b decays average ~300 μm; less than 100μm for c decays.
- Track momenta can be as low as 1GeV, so impact parameter resolution at low momentum is important

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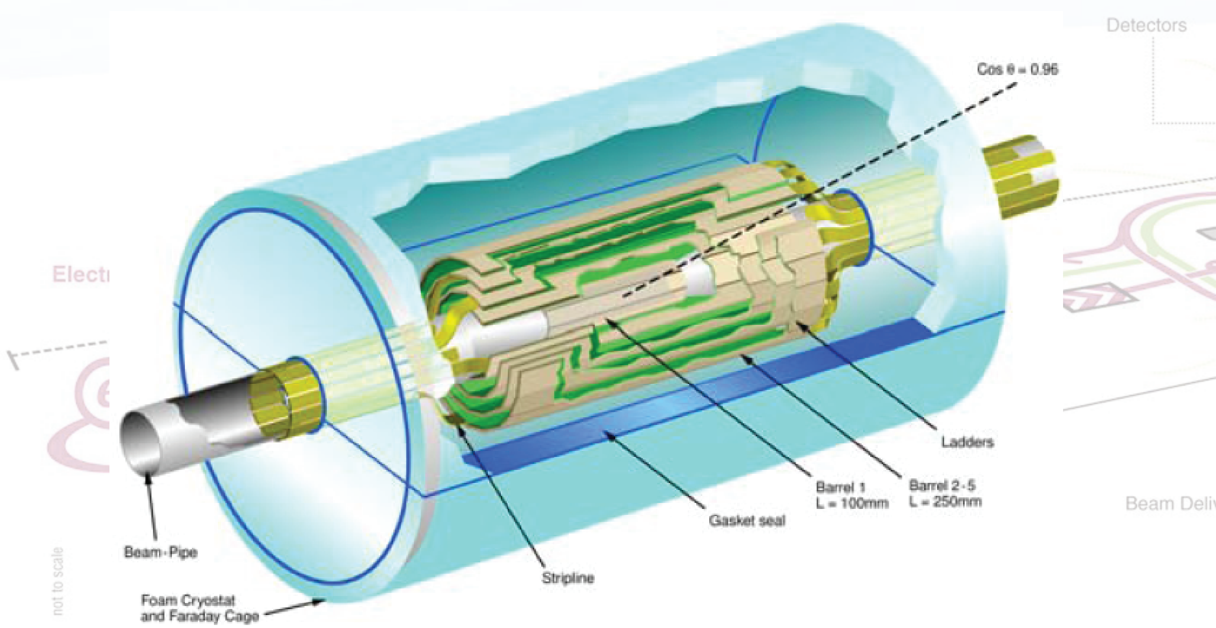
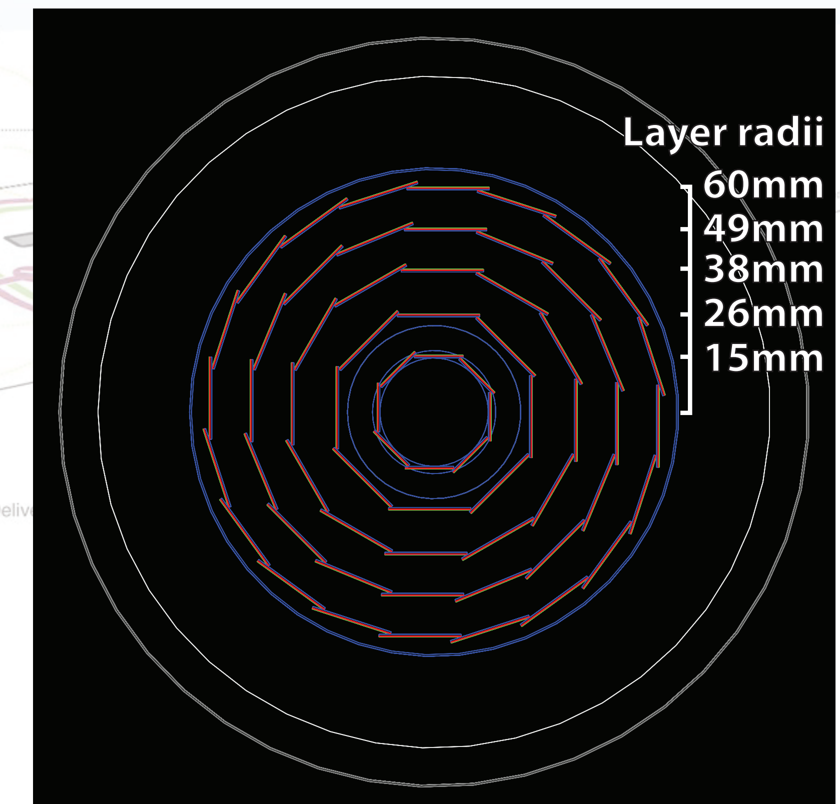
[1] LC-PHSM-2000-021

Vertex detector design

- Silicon pixel detector
- Innermost layer needs to be as close to the beampipe as possible.
- Barrel region has been shown to have impact parameter resolution < 10 μm down to track momenta of 1 GeV.
- Higher momenta has resolution down to 2-3μm





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Flavour Tagging

- Use two neural nets, one to tag each jet for b flavour, and one for c flavour

- Results are a value between 0 and 1

- These are used to create an event b-likeness and c-likeness using:

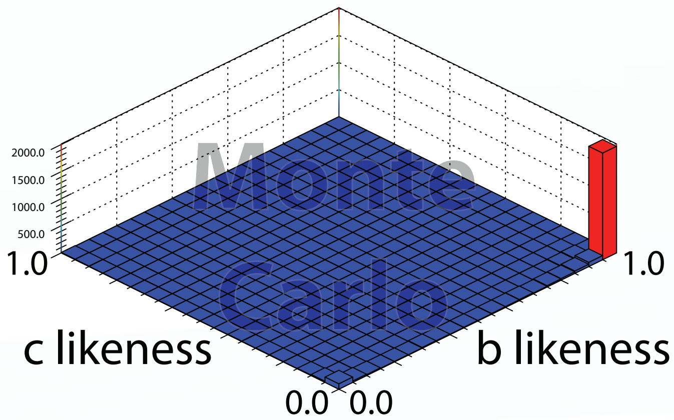
$$\text{b - likeness} = \frac{\text{b tag jet 1} \bullet \text{b tag jet 2}}{\text{b tag jet 1} \bullet \text{b tag jet 2} + (1 - \text{b tag jet 1}) \bullet (1 - \text{b tag jet 2})}$$

Likewise for c - likeness

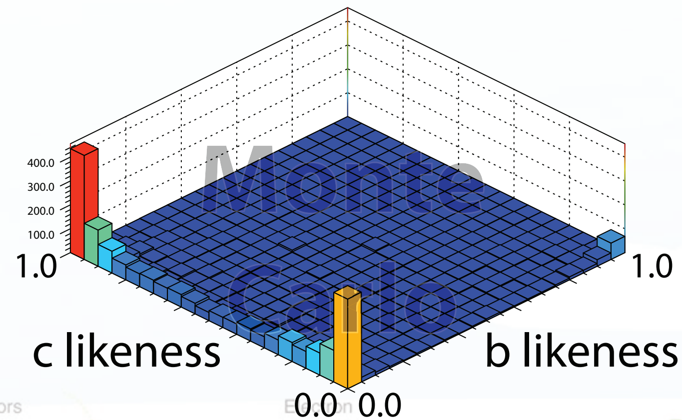
this basically only gives a high value if <u>both</u> jets have a high tag value.

Branching ratio extraction

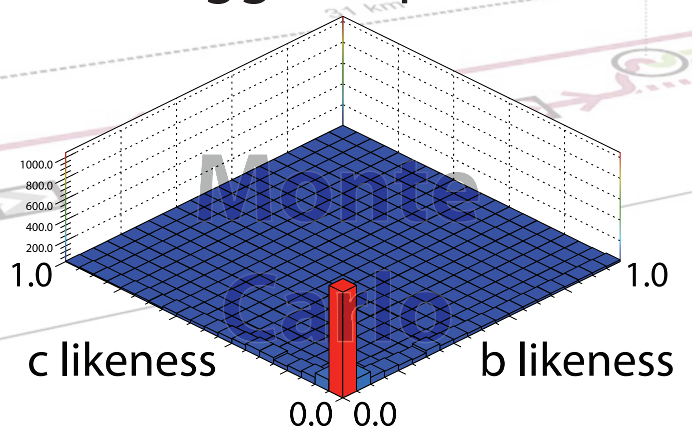
$b\bar{b}$ sample



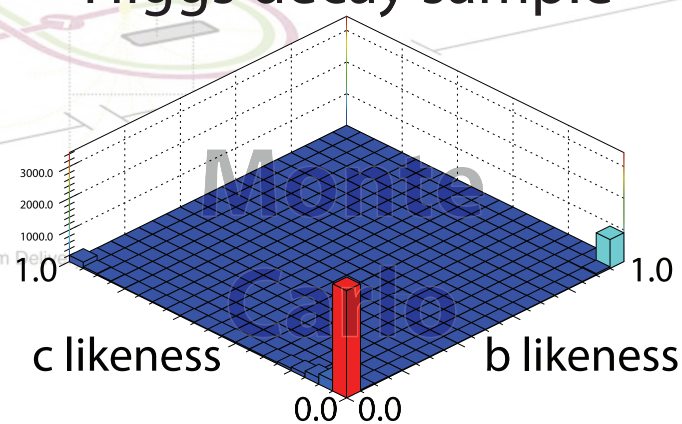
$c\bar{c}$ sample



gg sample



Background and other Higgs decay sample



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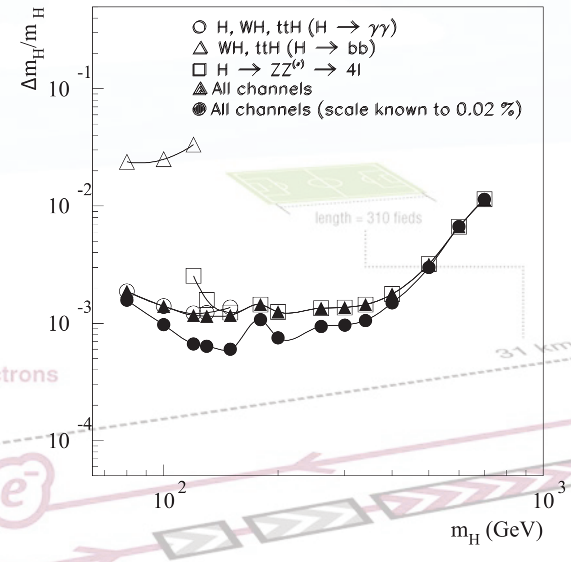
Summary

Using an electron - positron collider provides excellent Higgs measurements

Higgs mass measurement at ATLAS



At the LHC a light Higgs mass could be measured to a precision ~0.1%

At the ILC measured to ~50 MeV

At the LHC σ•BR measured to ~6-20%

At the ILC model independent absolute branching ratios measured to ~1-10%

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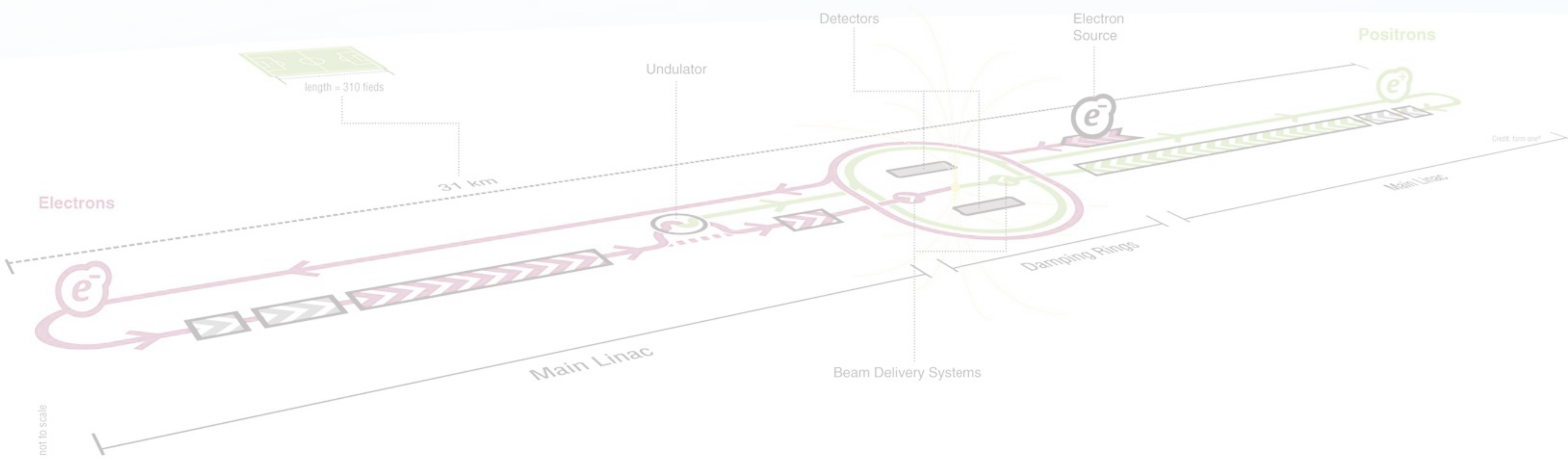

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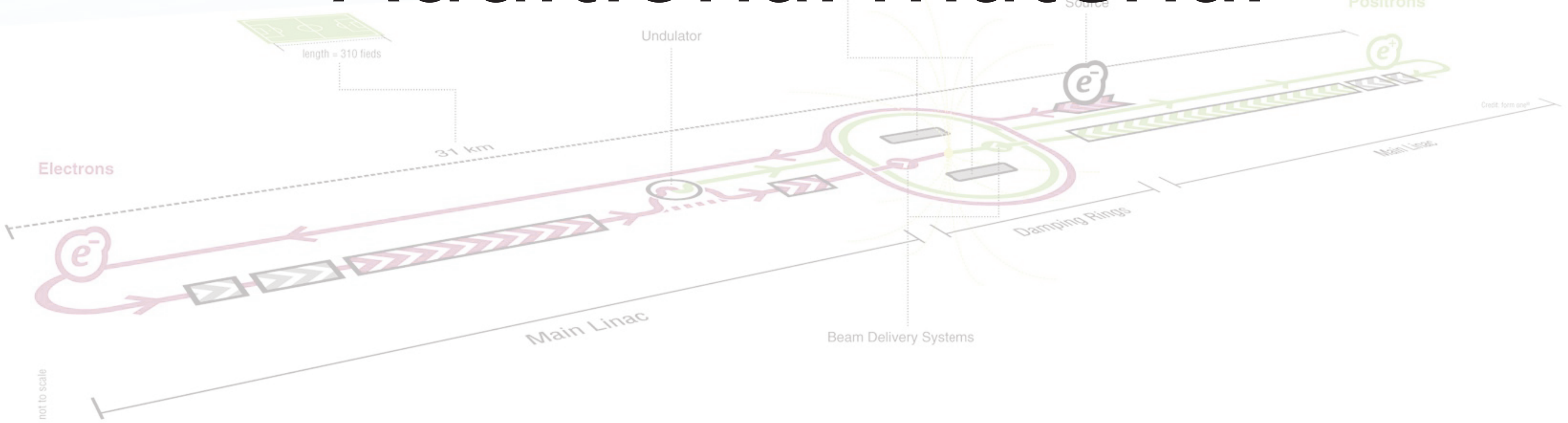
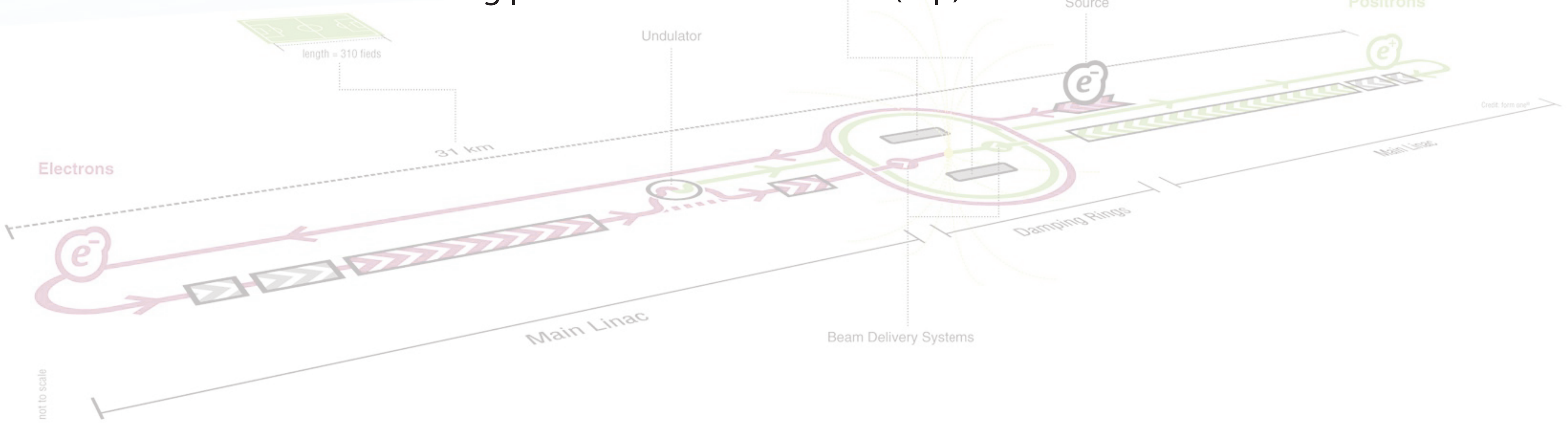
Additional material



Expected fractional errors

BR(H->bb)	1%
BR(H->cc)	12%
BR(H->gg)	8%

Higgs mass measured to 50 MeV by recoil from the Z requires tracking performance better than $\delta(1/p)$ 7×10^{-5} GeV^{-1}



Flavour tag neural net inputs

1 vertex found

$$tanh\left(\frac{D0Significance1}{100}\right)$$

$$tanh\left(\frac{D0Significance2}{100}\right)$$

$$tanh\left(\frac{Z0Significance1}{100}\right)$$

$$tanh\left(\frac{Z0Significance2}{100}\right)$$

$$JointProbRPhi$$

$$JointProbZ$$

$$tanh\left(\frac{3 \times Momentum1}{E}\right)$$

$$tanh\left(\frac{3 \times Momentum2}{E}\right)$$

2 or more vertices found

$$tanh\left(\frac{DecayLengthSignificance}{6 \times E}\right)$$

$$tanh\left(\frac{DecayLength}{10}\right)$$

$$tanh\left(\frac{PTMassCorrection}{5}\right)$$

$$tanh\left(\frac{RawMomentum}{E}\right)$$

$$JointProbRPhi$$

$$JointProbZ$$

$$tanh\left(\frac{NumTracksInVertices}{10}\right)$$

$$SecondaryVertexProbability$$

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$$\text{b-likeness} = \frac{\text{b tag jet 1} \bullet \text{b tag jet 2}}{\text{b tag jet 1} \bullet \text{b tag jet 2} + (1 - \text{b tag jet 1}) \bullet (1 - \text{b tag jet 2})}$$

Likewise for c - likeness

Likelihood function (due to the definition this should actually be minimised):

$$-2 \log L (r_{bb}, r_{cc}, r_{gg}) = \sum_{i=1}^{n_{ch}} \sum_{j=1}^{n_b} \sum_{k=1}^{n_c} \frac{\left(N_{ijk}^{data} - \sum_{s=(bb,cc,gg,bkg)} r_s N_{ijk}^{s}\right)^2}{N_{ijk}^{data}}$$

The only channel used so far is the lepton channel, so there is currently no sum over "i".

$$\sigma(e^+ e^- \rightarrow HZ) \times BR(H \rightarrow s) = r_s \times BR(H \rightarrow s)_{SM} \times \sigma(e^+ e^- \rightarrow HZ)_{SM}$$

To get the absolute branching ratios, this has to be divided by the measured total cross section, calculated from the recoil mass distribution

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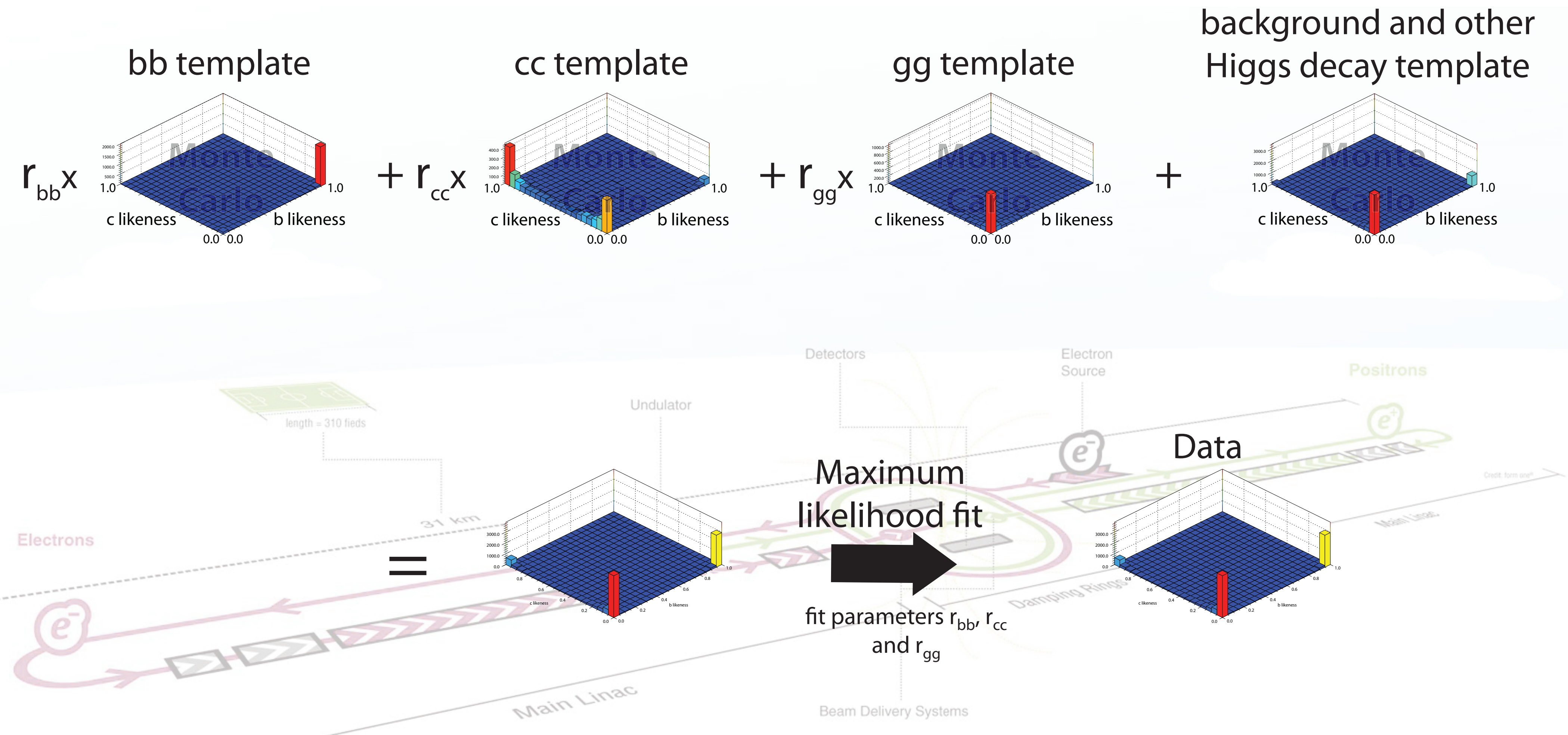

The fitted values of r_{bb}, r_{cc} and r_{gg} give the ratio of the branching ratio to the standard model branching ratio

(after taking account of the cross sections)