A further look at pysics analysis at HALHF - beam-beam effects

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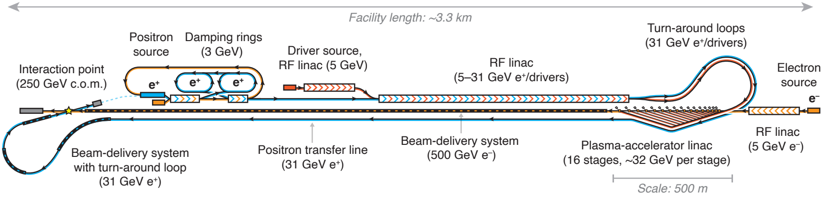
FC@DESY Meeting, July 7, 2023

CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE

Hybrid Asymmetric Linear Higgs Factory (HALHF)



- So we have
  - E(e^-) = 500 GeV, E(e^+) = 31.3 GeV $\Rightarrow E_{cm} = 2\sqrt{500 \cdot 31} = 249$ GeV.

Experimental conditions at HALHF

First look at the experimental implications of the HALHF.

- Generate with Whizard. Settings:
  - E(e$^-$) = 500 GeV, E(e$^+$) = 31 GeV $\Rightarrow E_{cm} = 2\sqrt{500 \cdot 31} = 249$ GeV.
  - No beam-spectrum (not yet available), no crossing angle, no polarisation.
  - But ISR - the worst spoiler of the recoil mass - is included.
  - Simulate ILD or ILD$'$ with SGV.
- Look at
  - Golden process: $e^+e^- \to ZH, Z \to \mu\mu$.
  - $e^+e^- \to \mu\mu$.
  - Track momentum resolution.

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Higgs recoil at HALHF

- Look at $\mathrm{e}^+\mathrm{e}^- \rightarrow ZH, Z \rightarrow \mu\mu$.
- Red-dash: HALHF, black-solid: same conditions, but E(e^-) = E(e^+) = 124.5
  - $\cos\theta$ of the muons ...
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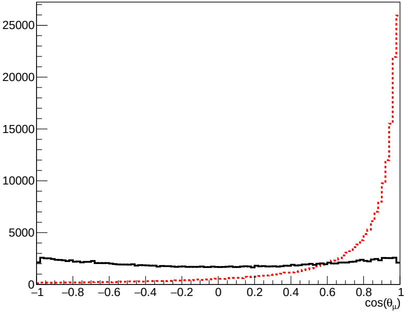

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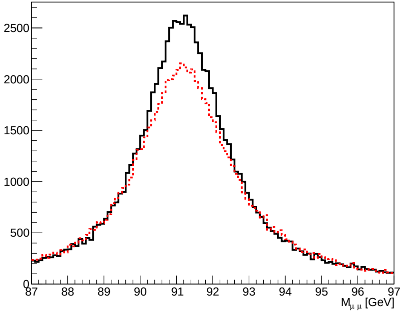

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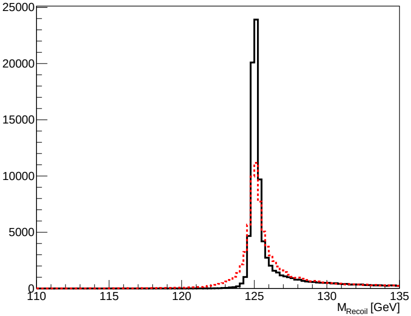

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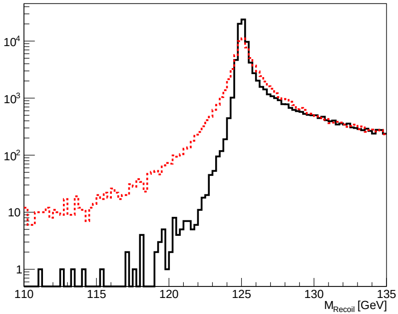

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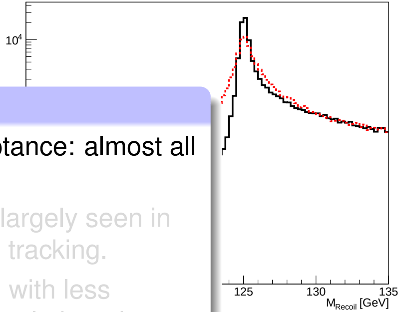

Preliminary uptake

- The problem is not acceptance: almost all μ:s are seen.
- Rather, it is that they are largely seen in the much weaker forward tracking.
- This can't be ameliorated with less material or better point-resolution: the problem is the lever-arm!
- So, either the forward region needs to be made longer, or the B-field must be modified ...

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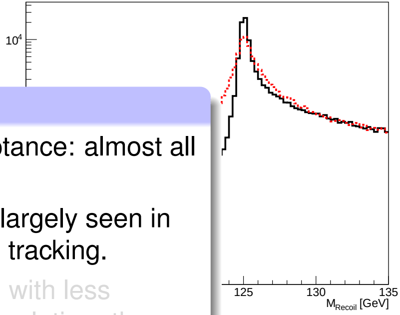

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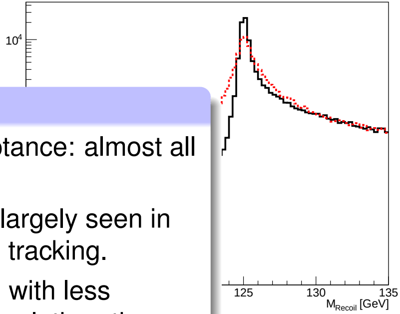

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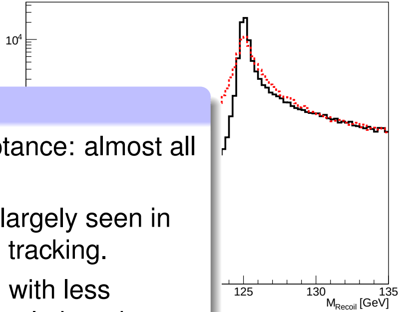

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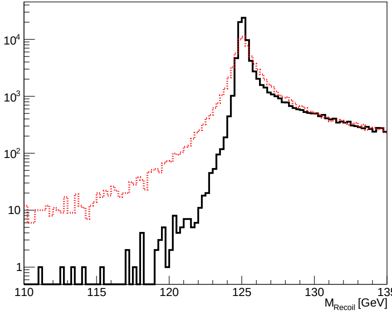
Modify detector length (Easy to do with SGV)

- ILD at ILC and ILD at HALHF
- and ILD made twice longer in the forward at HALHF
- and ILD made twice longer in the forward, but reduce TPC radius from 1.8 m to 1.55 m $\Rightarrow$ about the same size (Solenoid volume, area of detectors).
- Long-ILD would give a recoil-mass peak about 80% lower $\Rightarrow$ very roughly S/B 20% worse $\Rightarrow$ $\sim$ 60% more integrated luminosity needed.



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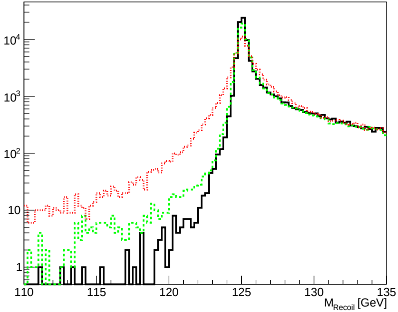

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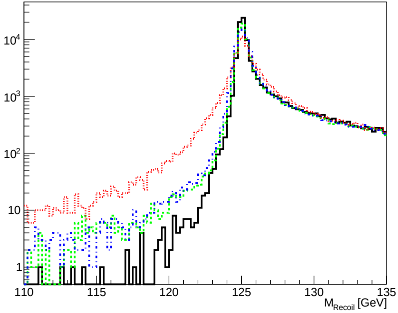

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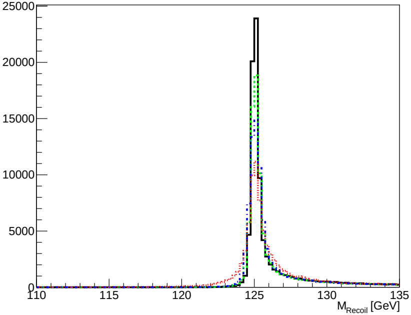

Muon pairs at HALHF

What about fermion pairs, and things like A_{FB} ?

- Generate $\mathrm{e}^+\mathrm{e}^- \rightarrow \mu^+\mu^-$, and look at Pseudorapidity of μ^+(dashed) and μ^- (solid), separately. Black is ILD@ILC, Red is longer, R-reduced ILD at HALHF.
- In the lab-frame ...
- ... or the CM frame.
- $\Rightarrow$ The symmetry is broken - loss in the forward, but gain in the backward - Maybe that partly compensates ? Also slightly wider ...

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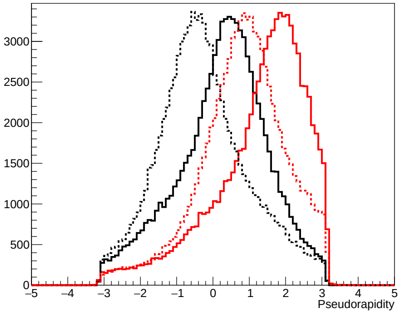

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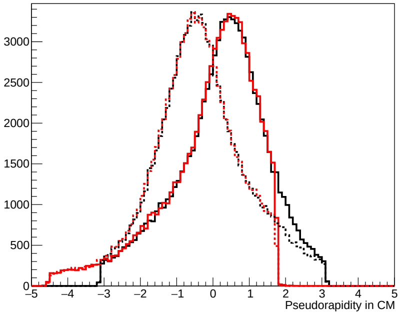

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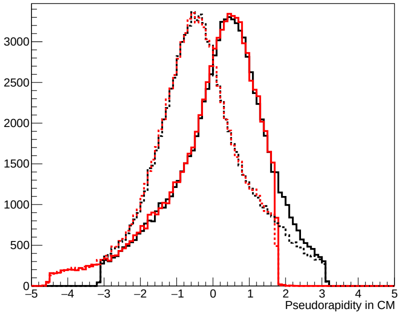

Experimental conditions at HALHF: Track momentum resolution

- Standard ILD-at-ILC: $\sigma(1/p_T)$ vs. p
- To compare apples with apples with boosted system: look at $\sigma(p)$ vs. p
  - Not $\propto p^2$, rather to P^1.
  - ... because M.S. dominates all over.
- Now, in HALHF, but look at $\sigma(p)$ vs. p *in the CM system*: Apples with apples:
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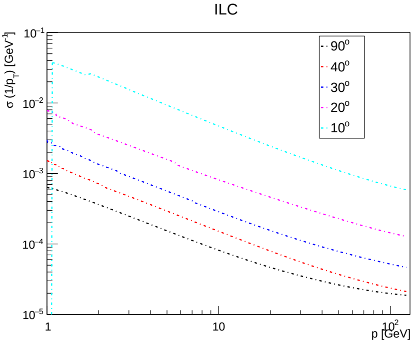

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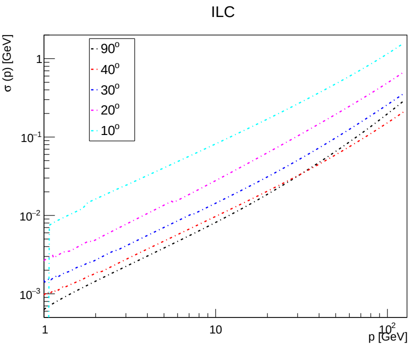

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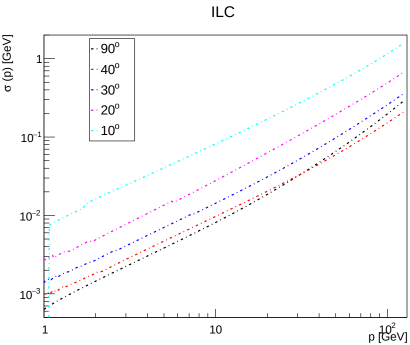

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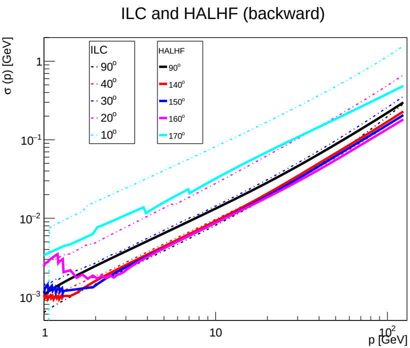

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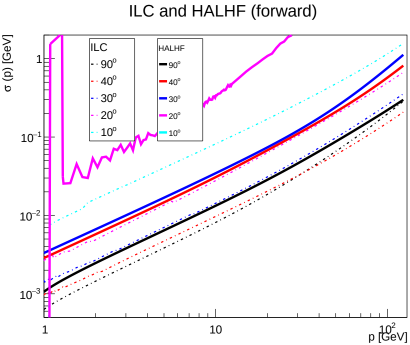

Bhabha at HALHF

What about Bhabhas, the standard candle for luminosity measurement?

- Luminosity is a source of systematic errors everywhere.
- $\Rightarrow$ need per mil level control.
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Optimising power consumption for HALHF

- Assume wall-plug-to-beam efficiency is the same for any case.
- Energy-symmetric collisions clearly are the most efficient: No energy wasted in giving the final state kinetic energy.
- However, one can play with how many particles are accelerated on each side: The luminosity scales with the product of the bunch-charges.
- So decreasing the charges on the high-energy side, increasing on the low-energy one reduces the total beam-power.
- In the HALHF case, with $E_{high} = 16 \times E_{low}$, the optimum is 4, i.e. increase the positron bunch charge by a factor 4, decrease the electron one to 1/4.
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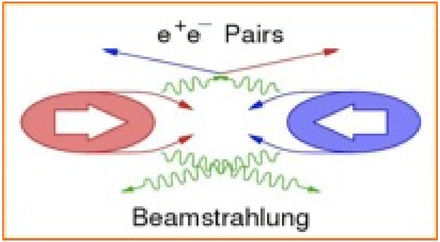
The issue: Beam-strahlung pairs

- The strong fields inside the bunches generate a large flux of photons.
- These generate e^+e^- pairs.
- Lots of pairs: SiD simulation ...
- The pairs concentrate along a curve $p_\perp \propto \frac{1}{\Theta}$
- $\Rightarrow$ Plot $\lg p_\perp$ vs. $\lg \Theta$: ILC@250 with “SetA” parameters, and ILD.
- Where the sharp edge is depends strongly on the beam-parameters (emittace, beta-function, bunch-charge and -length...)
- This MUST stay in the beam-pipe !
- Tool: GuineaPig by D. Schulte.



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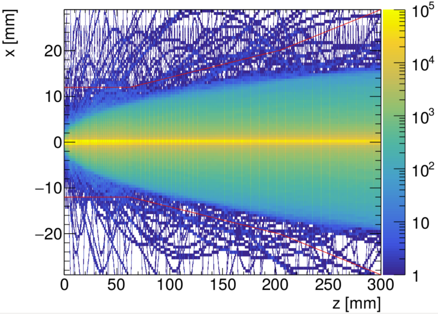

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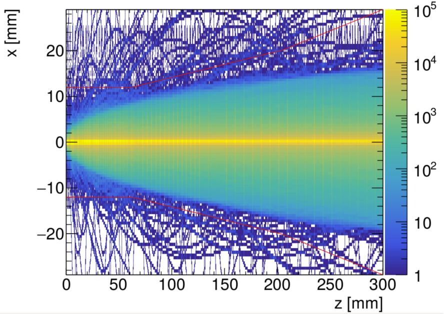

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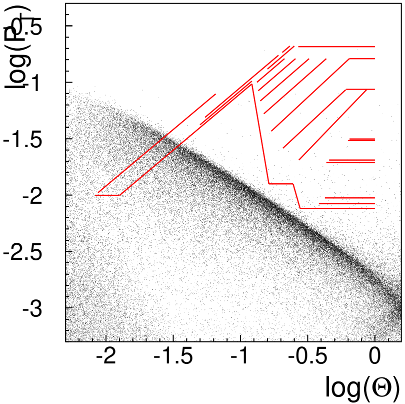

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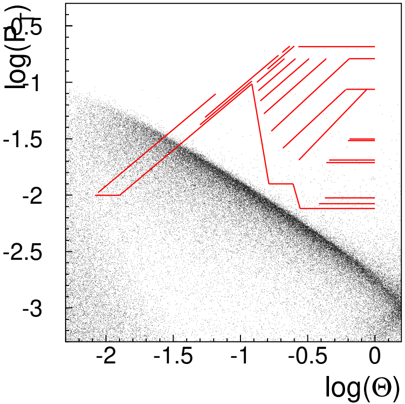

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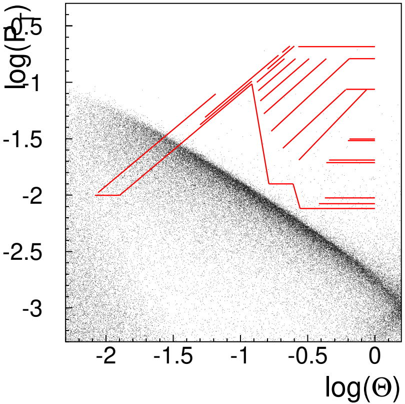
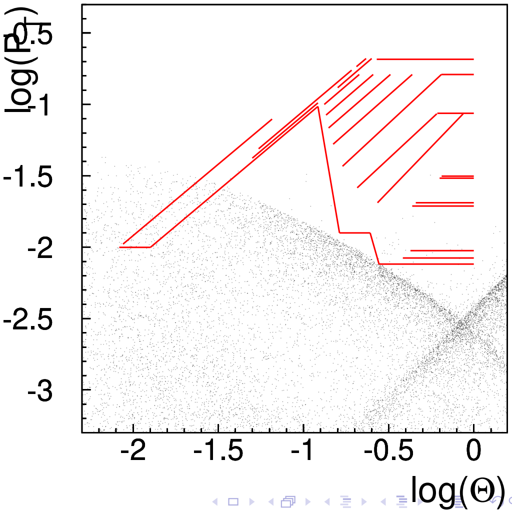


Pairs in HALHF with asymmetric E and asymmetric bunch-charge, $\sigma_z = 75\mu$

- Lumi: 0.83 μb^{-1}/BX = "ILC"$\times$0.78. 62k pairs, w/ 706 TeV
- Power: ILC$\times$1.25
- Backward
- But...
- Forward
- Not good ...



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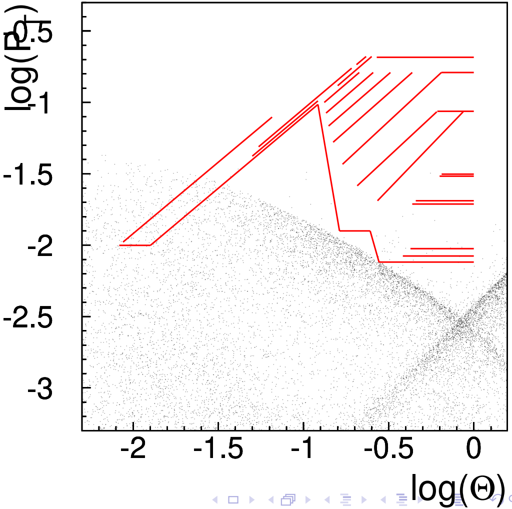

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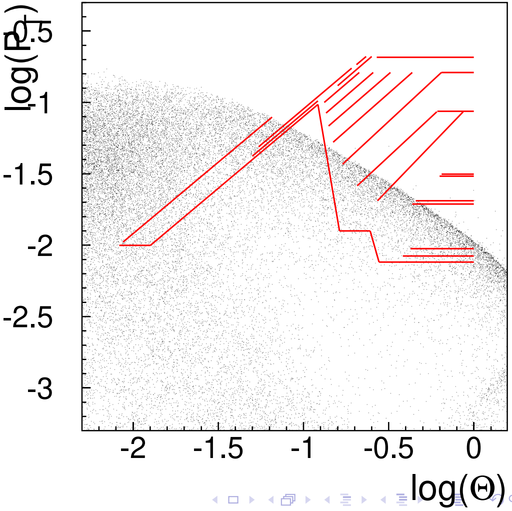

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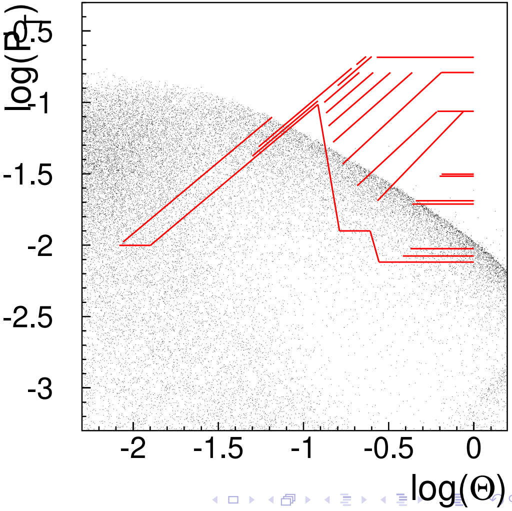

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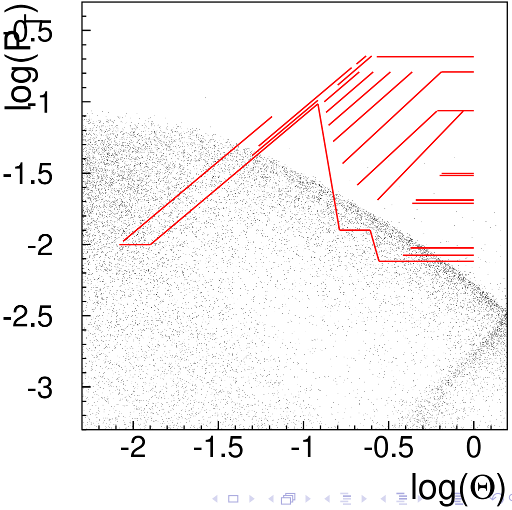
- Lumi: 0.80 μb^{-1}/BX = "ILC"$\times$0.75 . 52k pairs, w/ 341 TeV
- Power: ILC$\times$2.13
- Forward
- Still not good ...



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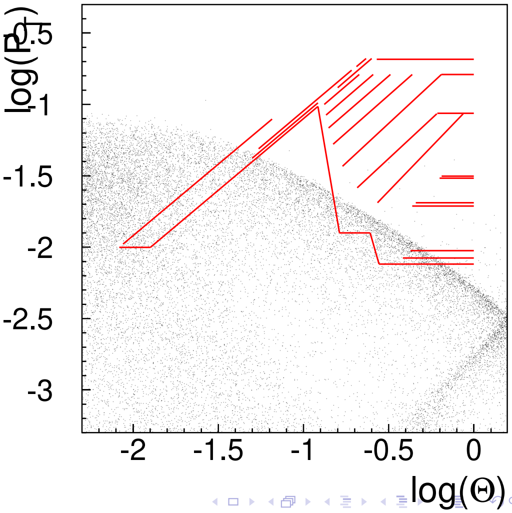
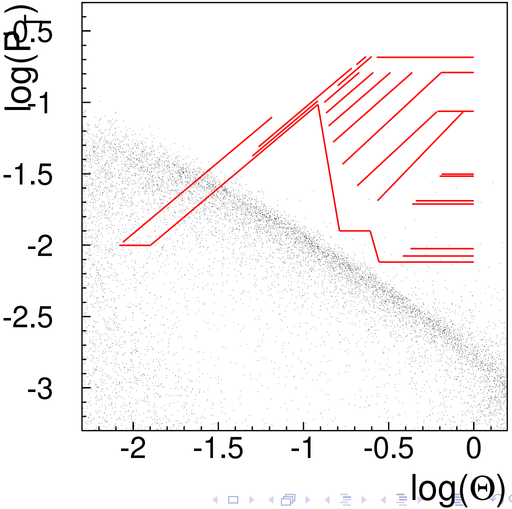


Pairs in HALHF with asymmetric E and symmetric bunch-charge, $\sigma_z = 300\mu$

- Lumi: 0.75 μb^{-1}/BX = "ILC"$\times$0.71. 48k pairs, w/ 185 TeV
- Power: ILC$\times$2.13
- Forward
- OK !



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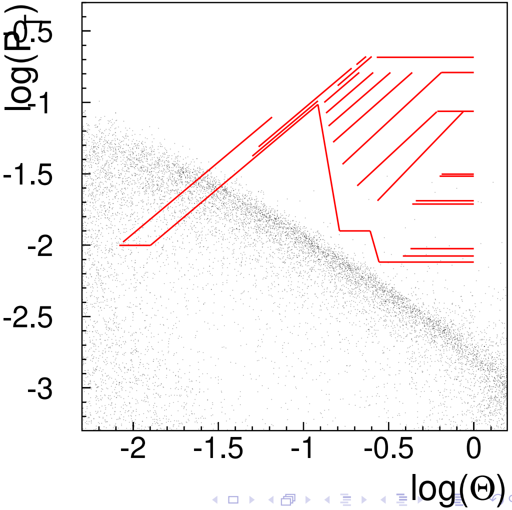
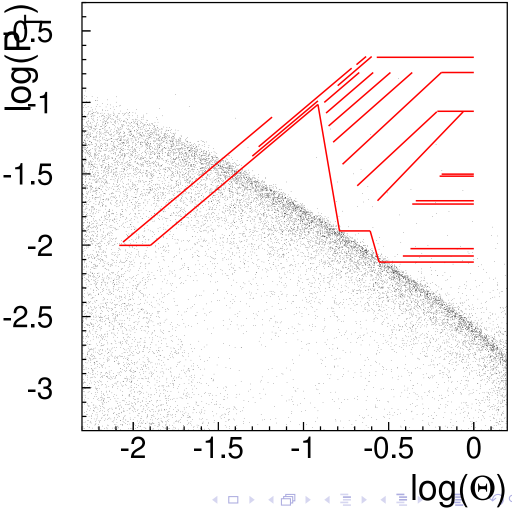


Pairs in HALHF with asymmetric E and modified asymmetric bunch-charge, $\sigma_z = 300\mu$

- Charges: 1.33 and 3 $\times 10^{10}$ particles per bunch.
- Lumi: 0.71 μb^{-1}/BX = "ILC"$\times$0.67. 47k pairs, w/ 215 TeV
- Power: ILC$\times$1.52
- Forward, 3.5T
- $\sim$ OK, but
- Forward, 5T
- OK.
- Forward, 5T, longer
- Also $\sim$ OK



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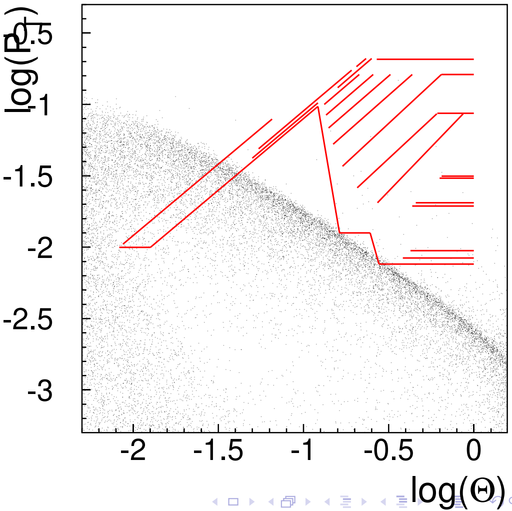

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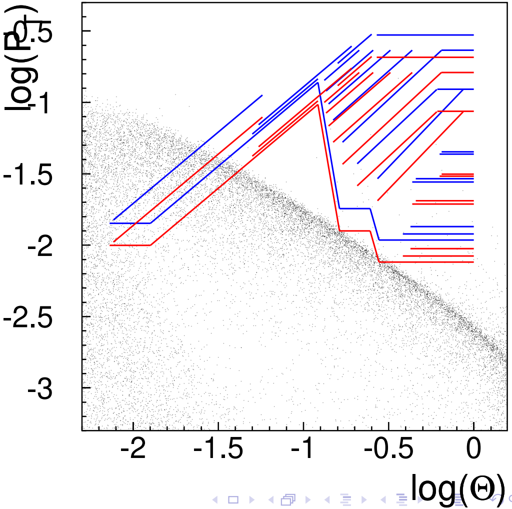

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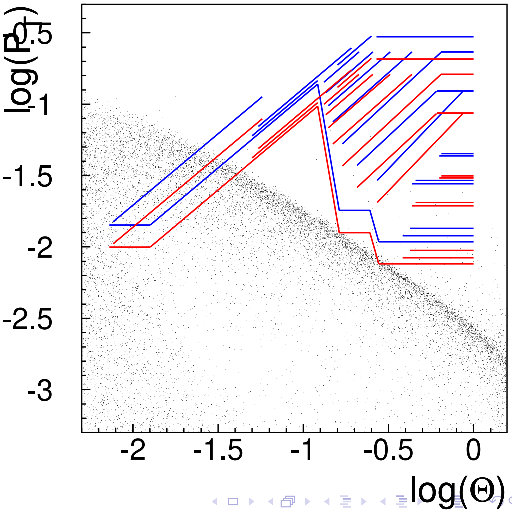

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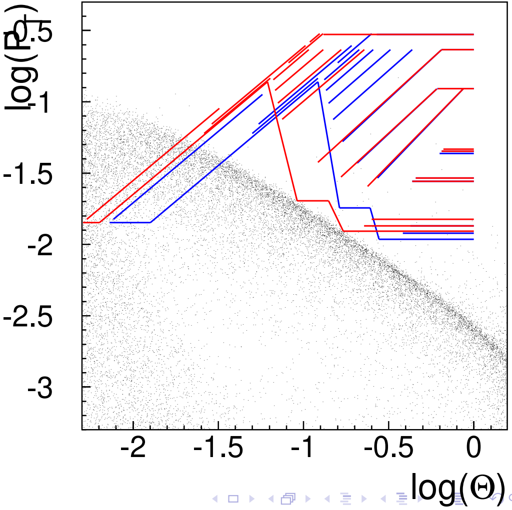

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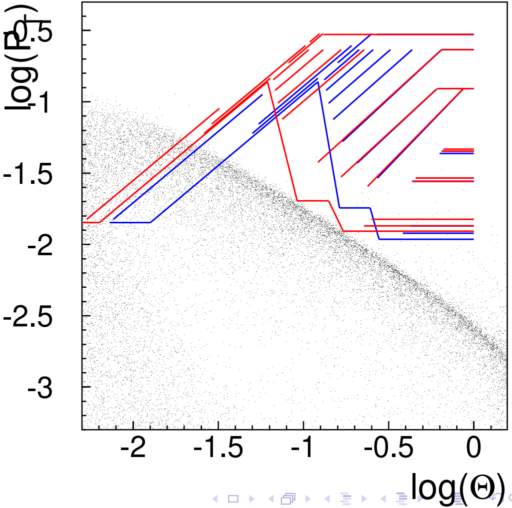

Conclusions and TODO

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But more work needed:

- Beam-spectrum - but already in hand with the GuineaPig setup (needs more stat, and post-treatment)
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