# The virtual $\gamma$ saga

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ILD SW&ANA phone meeting

# The virtual $\gamma$ saga: Intro

- The process $e^+e^- \to e^+e^- + f\bar{f}$ is difficult to generate: If the 4-momentum transfer between incoming and outgoing $e^{+(-)}$ (= $q \approx$ the scattering angle) becomes small, the process is dominated by scattering of virtual $\gamma$:s radiated off the $e^{+(-)}$
- It becomes very hard to evaluate the phase-space integral from the full M.E. treatment, and event-generation becomes very slow.
- At some lowest $q$, we switch from the M.E. treatment to the *equivalent photon approximation* (EPA), where the flux of virtual (or better "quasi-real") photons is evaluated, and the process becomes $\gamma\gamma \to f\bar{f}$, i.e. a $2 \to 2$ process.
- NB: In both cases, there is a minimum $M_{f\bar{f}}$ (4 GeV for $\mu$:s and e:s, $2\times M_\tau$ for $\tau$:s, 10 GeV for quarks)

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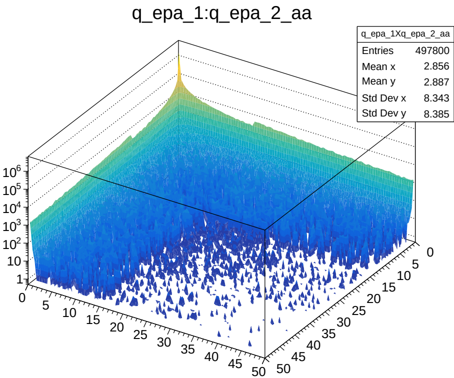

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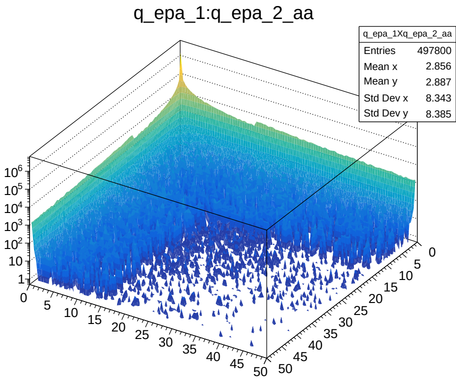

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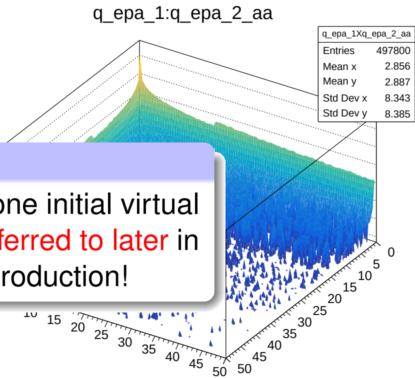


**So:**

All channels with at least one initial virtual $\gamma$ have up to now been deferred to later in the 250 GeV mass-production!

# The virtual $\gamma$ saga: Problem solved!

- News from Wolfgang Kilian (WHIZARD author):
  - There *is* indeed a factor $\equiv 2$ missing per virtual photon if beam-polarisation is on !
- It is clear that the default cut in $Q^2$ between the M.E. and the EPA methods of generating $e^+e^- \rightarrow e^+e^- + X$ is too high wrt the cut on $m_X$.
- This I've studied, and found that $\sqrt{|Q^2|} = 0.2$ is a good separation, even for a cut $m_X$ at 4. The cut in $\sqrt{|Q^2|}$ in the existing M.E. samples is at 4, so there is a missing part for $\sqrt{|Q^2|} \in [0.2, 4]$
- Tip from Filip:
  - There *is* a way to emulate an *OR* in the cuts-definition in the sindarin ($a \vee b \Leftrightarrow \neg(\neg a \wedge \neg b)$ ...) $\Rightarrow$ The "L-shaped" missing phase-space in the M.E. part of $e^+e^- \rightarrow e^+e^- + X$ can be generated in a single step.

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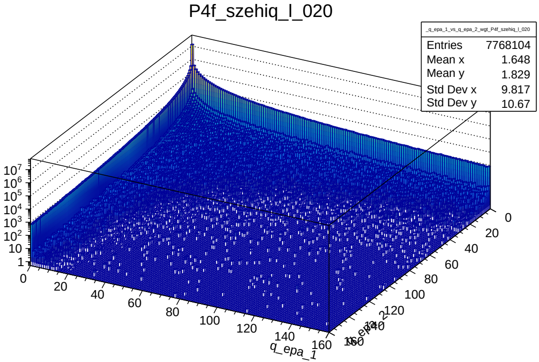
# $Q^2$ vs. $Q^2$

- Full range ($\gamma\gamma$, e$^+$/e$^-$$\gamma$ and M.E. high and low $Q^2$)
- Transition M.E. high and low $Q^2$
- and zoom in $\Rightarrow$ OK.
- Transition M.E. to EPA
- and zoom in
- ... and scale w/ $\equiv 2$ per EPA $\gamma \Rightarrow$ OK !



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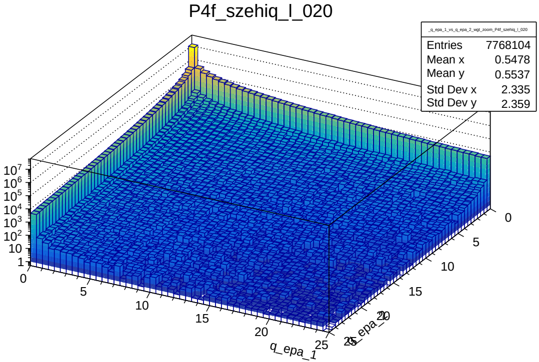

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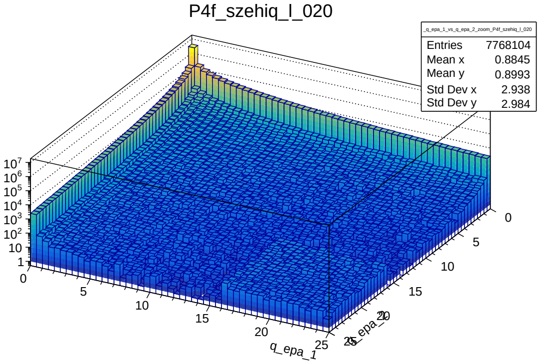

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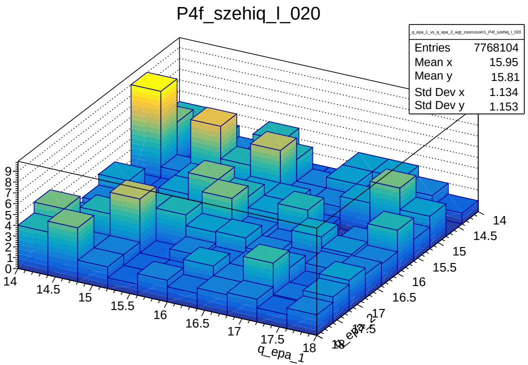

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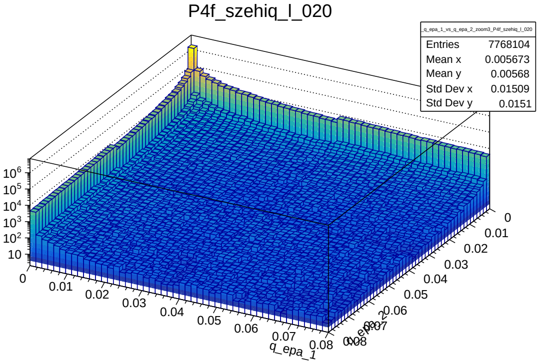

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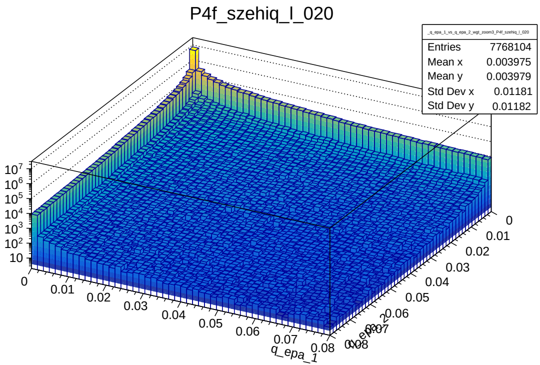

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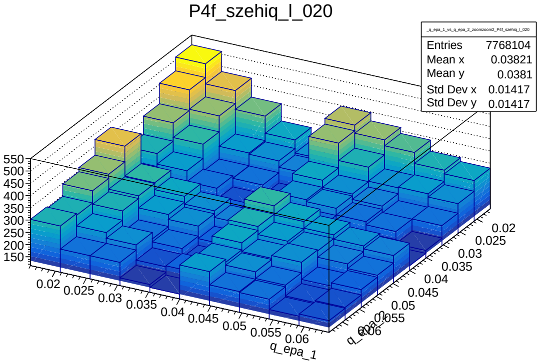

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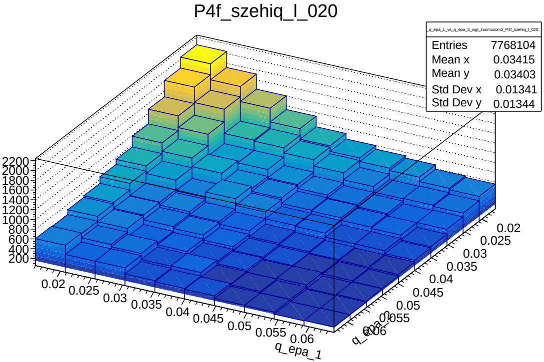
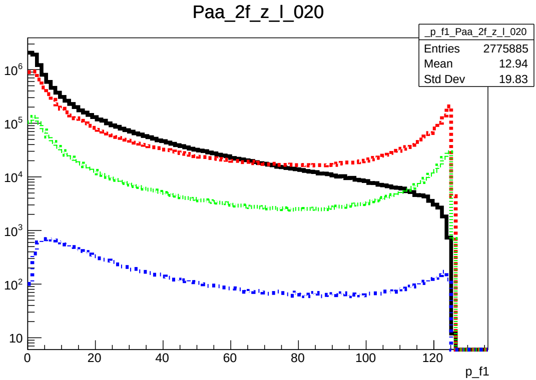


# Properties of new events (for $\int \mathcal{L} = 5 \text{ fb}^{-1}$)

In all plots: black = aa, red = ae, green = M.E., low $Q^2$, and blue = M.E., high $Q^2$.

- Muon $p$
- Muon $p_T$
- Di-muon mass
- Di-muon mass, both $\mu$:s in tracking.
- Recoil-mass
- Recoil-mass, $m_{\mu\mu}$ close to $m_Z \Rightarrow$ Higgs to invisible, anyone ?



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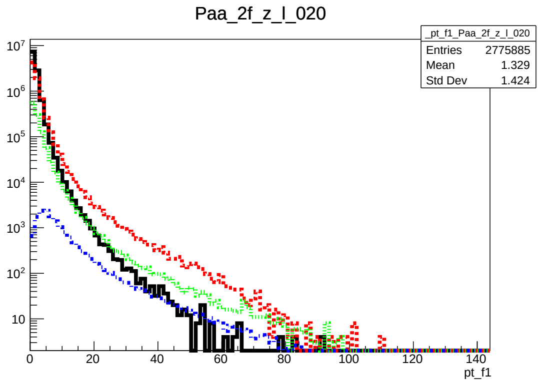

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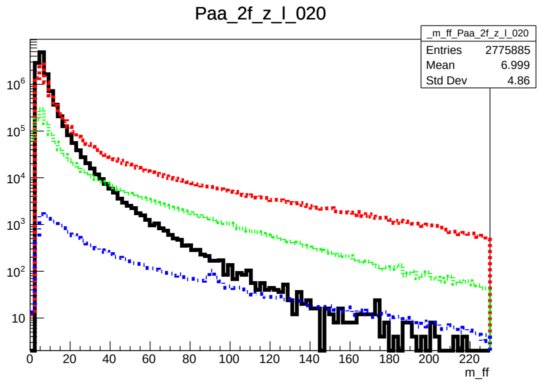

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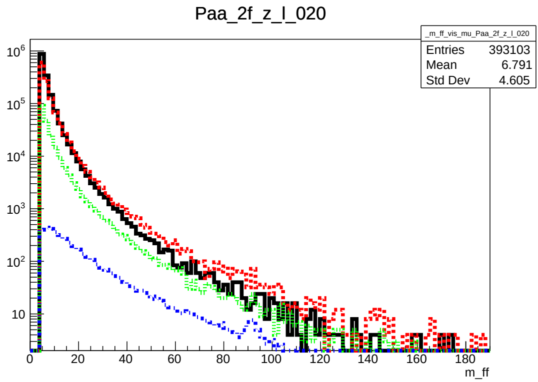

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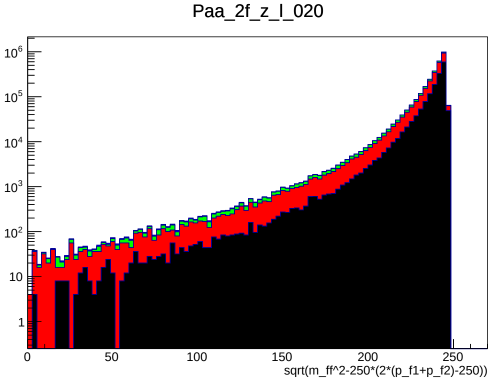

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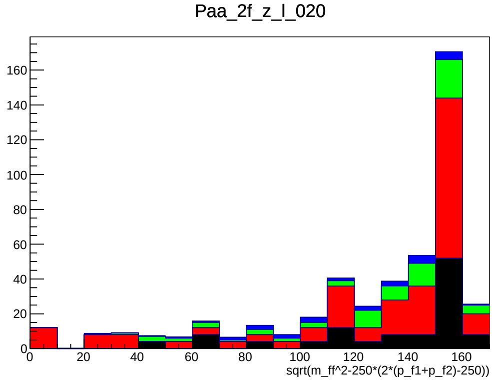


# Cross-sections of new samples

| sample | leptonic pb | hadronic pb | # Mevents | suggestion (∼ 1 year) |
|---|---|---|---|---|
| aa_2f | 2220 | 122 | 2342 | 426 |
| ae_3f | 1490 | 139 | 3258 | 296 |
| ea_3f | 1486 | 140 | 3252 | 296 |
| 4f_szeloq (LL and RR) | 442 | 68.5 | 27 | 27 |
| 4f_szeloq (LR and RL) | 448 | 69.1 | 138 | 138 |
| Total | | | 9017 | 1183 |

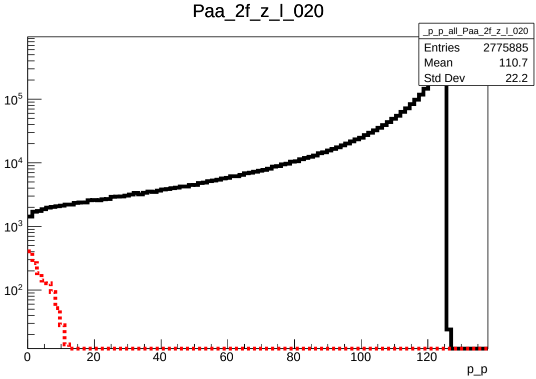
Numbers using the standard assumptions: 1 $ab^{-1}$ for each of aa_2f, ae_3f and ea_3f (for the latter two: $\times$ 2 polarisations), 1 $ab^{-1}$ for each of 4f_szeloq LR and RL, and 0.2 $ab^{-1}$ for each of 4f_szeloq LL and RR.

However: Note that the standard assumptions is *a lot*. The 5/1/1/5 $ab^{-1}$ for the "normal" samples is $\sim$ 10 times the full H20 statistics, and the reduced 1/0.2/0.2/1 is still more than the 11 years of H20 running, except for aa_2f, where it is about 1/2 of H20 .

# Small events ....

For aa_2f:

- Just 0.04 % of the events will have a beam-remnant seen in the BeamCal, and then it only deposits a few GeV.
- The energy of the $f\bar{f}$ system, for events where both $f$:s are above 7 deg.
- So, typically there is only a few GeV that hits *anything* in these events.



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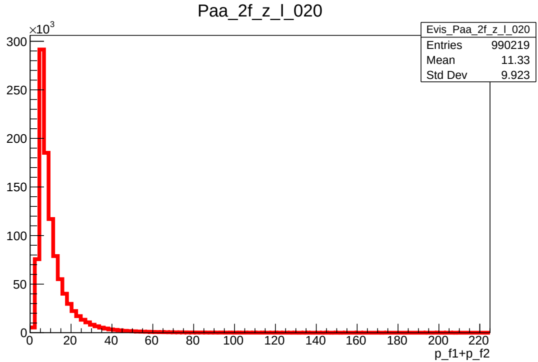

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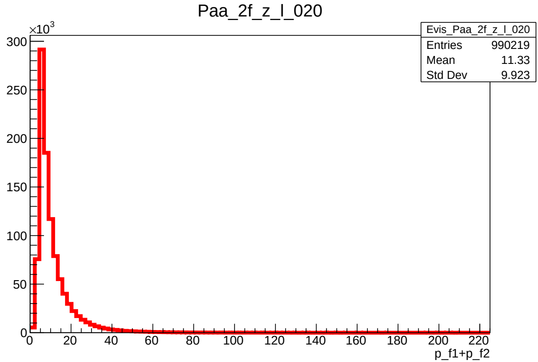

# Small events ....

- So, the average seen energy for the aa_2f class is only 11 GeV = 4 % of 250 GeV.
- Also the ae/ea_3f events are smaller than "typical" events: One beam-remnant is down the beam-pipe, but also the other, high $Q^2$, one is in 25 % of the events.
- The average seen energy is $\sim$ 94 GeV in this case = 37 % of 250 GeV.
- Both aa_2f and ae/ea_3f are mainly leptonic: 94 % and 91 %, respectively.
- All this indicates that simulation ($\propto E_{vis}$), and reconstruction ($\propto E_{vis}$ and multiplicity) should be much faster than for the "typical" events.
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# Conclusion and out-look

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- Need to check how much of these we can afford to generate:
  - Cross-sections are Huge...
  - ... but events are small.
- $\Rightarrow$ Need to check simulation and reconstruction for CPU and disk-space/event, and then decide.
- Note that even though the big samples are only 9 channels, there are lots of small cross-section channels also to be done ($e^+e^- \to e^+e^- + f\bar{f}f'\bar{f}'$ ...).
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